

Intermittent Escalator Study

As required by

The Energy Policy Act of 2005 Public Law 109-58, Sec. 138



Prepared by

The National Institute of Building Sciences
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Executive Summary

In the Energy Policy Act of 2005, Congress required the General Services Administration (GSA) to conduct a study of the advantages and disadvantages of employing intermittent escalators in the United States and report the findings based on energy efficiency, life cycle cost (LCC), safety, and other costs such as liability. The Act defines "intermittent escalator" to mean an escalator that remains in a stationary position until it automatically operates at the approach of a passenger, returning to a stationary position after the passenger completes passage.

The National Institute of Building Sciences (NIBS) and GSA convened a panel of industry experts comprised of representatives from manufacturers, installers, code officials, standards organizations, and building owners and operators, such as public transit, to participate in the study effort. The industry expert panel evaluated the application of intermittent escalator technology in the U.S., addressing cost differentials and energy savings, as well as life safety, liability, and litigation concerns. Both new construction and retrofit of existing installations were included in the analysis. This document from the industry expert panel serves as the GSA report to Congress.

The American Society of Mechanical Engineers (ASME) sets the industrial and manufacturing codes and standards that govern the public safety of elevators and escalators. The application of this code extends to all areas of the vertical transportation industry. Other U.S. code-developing organizations, such as the International Code Council (ICC) and the National Fire Protection Association (NFPA), defer to ASME A17.1 for escalator design and construction standards. The GSA's "Facility Standards for the Public Buildings Service" (PBS-P100) incorporates ASME A17.1 as the basis for escalator design in its capital construction projects.

The use of intermittent escalators has been prohibited by ASME A17.1 since 1988. Specifically, ASME A17.1 prohibits both variation in speed after the start-up of an escalator and automatic starting or stopping of an escalator.

The Energy Policy Act defines an intermittent escalator as one that starts and stops; however, that is no longer the industry standard. Based on use of intermittent escalators in Europe, Asia, and Canada, the manufacturers do not recommend that the escalator come to a complete stop, but that standby or sleep mode be used. Today, the industry standard is to reduce the escalator speed to sleep mode, when no passengers are riding, and bring the escalator up to full speed when a passenger approaches.

This study on the use of intermittent escalators looked at the potential for applying this technology in the U.S., addressing cost differentials and energy savings, as well as life safety, liability, and litigation concerns. The benefits of energy savings, lower life cycle expenses, and the perception of building "green" are valuable to building owners and operators. However, the potential safety hazards which lead to increased insurance costs and the threat of litigation are the biggest risks to building owners.

The industry expert panel determined that the two most important elements for a thorough study were:

- A traffic study to measure the amount of time an escalator ran without passengers so that the standby or sleep mode time could be determined and energy savings could be calculated.
- A risk/benefit analysis to balance the risks to passenger safety with the energy and operational cost savings to the owner.

The panel decided that the best approach for this study would be to evaluate an escalator most likely to produce energy and life cycle cost savings. The panel determined that if this "best case" scenario produced only limited energy savings then there was little to be gained from the evaluation of other escalators with heavier usage patterns. The panel found that it would be most appropriate to assess an escalator application that would provide a significant result. The panel reached consensus that the escalator presenting the greatest potential for analysis of cost savings and availability for study was a Washington Metropolitan Area Transit Authority (WMATA or Washington Metro) escalator in a station where the daily traffic fluctuates from moderate/heavy, at certain times of the day, to minimal, with periods of very little use.

RSMeans, with input from the industry expert panel, conducted a Life Cycle Cost (LCC) Study for intermittent escalators. Neither the traffic pattern for potential use nor the financial feasibility of intermittent escalators has been studied in the U.S., primarily due to the ASME A17.1 prohibitions on automatic start/stop and variable speed that prevent the use of intermittent escalators in the U.S.

When only energy costs were evaluated—and all construction costs were excluded—a Life Cycle Cost advantage emerged for the equipment investment for intermittent escalators, whether as new construction or as a retrofitted conventional escalator. The average life for new escalators would be extended; however, the exact length of time is undetermined.

Additional conclusions about financial impacts for the specific WMATA escalators analyzed in this study include the following:

- The payback period on the \$5500 cost for the sensors and motor control unit only—not including the approximate \$10,000-\$24,000 for design and construction costs—for a new Intermittent Escalator installation is 3.1 years for an Up escalator and 3.5 years for a Down escalator. If these additional design and construction costs are included in the payback period calculation, the payback period would be significantly longer.
- To retrofit standard conventional escalators the payback time on the \$8300 cost for the sensors and motor control unit only—not including the approximate \$10,000-\$24,000 for design and construction costs—is higher, at 4.6 years for an Up escalator and 5.2 years for a Down escalator. If these additional design and construction costs are included in the payback period calculation, the payback period would be significantly longer.
- The adjusted Internal Rate of Return for the sensors and motor control unit only—an initial investment cost of \$5500 for new and \$8300 for retrofit—is 11.95% for an Up escalator and 11.62% for a Down escalator. The Internal Rate of Return calculations do not include design and construction costs, which would significantly reduce the return rate. Actual design and construction costs would vary for each particular installation and could only be determined on a case-bycase basis at each specific escalator location.
- The Reinvestment Rate for the sensors and motor control unit only—an initial investment cost of \$5500 for new and \$8300 for retrofit—is 5%. As with the

Internal Rate of Return calculations, the Reinvestment Rate calculations do not include design and construction costs, which would significantly reduce the return rate. Actual design and construction costs would vary for each particular installation and could only be determined on a case-by-case basis at each specific escalator location.

It is important to note that the life cycle economic analysis does not include an analysis of architectural and engineering design or construction modifications to the existing escalator or surrounding space. Because all building layouts are different, it is imperative that each intermittent escalator application be evaluated for the impacts of the addition of length to entry and exit paths. The need for space modifications can significantly decrease the economic justification of intermittent escalators, and may make their selection from an economic standpoint prohibitive.

A true risk/benefit analysis is beyond the scope of this study. The industry expert panel did not have the expertise to fully evaluate the risks and costs of human injury. This study has provided a mechanism to calculate the benefits of energy and life cycle cost savings. The ASME contributed safety and risk information to this study based on presentations to the A17.1 Escalator and Moving Walk Committee by experts in human engineering studies; however, a more thorough evaluation of the safe use of intermittent escalators, commissioned by an organization such as the ASME, would likely produce more conclusive findings of risks.

The chief findings of the industry expert panel are –

Energy savings and rate of return on investment attributable to the use of intermittent escalators would be modest, at best, for low use scenarios, and overall savings could be significant only if employed broadly over a large inventory of escalators.

The actual cost to retrofit an escalator in an existing building was not calculated since the construction costs vary on a case-by-case basis. The flow of escalator passengers needs to be evaluated in any retrofit application, as would compliance with the Americans with Disabilities Act (ADA) and other applicable national codes and standards. Related design and construction costs to accomplish an appropriate retrofit for intermittent escalator capabilities could be significant and would likely make such an installation cost-prohibitive.

Although insufficient data exists to confirm this conclusion, the use of intermittent escalators probably would not significantly decrease the safety of escalators if used properly and if available safety precautions were implemented. However, if used improperly, as occurs frequently on conventional escalators in all locations, intermittent escalators would likely elevate the potential safety hazards associated with falls on escalators.

The use of intermittent escalators has the potential to significantly increase the liability and in turn litigation attached to escalator use, primarily because of user perceptions of movement differential. Litigation due to falls on escalators is already costly.

A risk/hazard analysis, commissioned through an organization such as the ASME, to document the safety of intermittent escalators is warranted. The results of such a study would enable the ASME to conduct an accurate and balanced review of the adoption of code revisions to permit or to continue the prohibition of intermittent escalators in the United States.

Other energy saving technologies, that do not require safety code revisions, are known to the manufacturers and merit study. These technologies are not compatible with intermittent escalator technology and were therefore beyond the scope of this report.

The industry expert panel concluded that, even if there were energy and economic savings and no discernible decrease in escalator safety, the potential for substantial liability costs in the present litigious climate will likely preclude the adoption and use of intermittent escalators in the United States.

Background

Legislation

In the Energy Policy Act of 2005, Congress required the General Services Administration (GSA) to conduct a study of the advantages and disadvantages of employing intermittent escalators in the United States and report the findings based on the following goals:

- Energy efficiency
- Life Cycle Cost (LCC)
- Safety
- Other costs such as liability

In response to the requirement to study all aspects of the technology and the potential use of intermittent escalators in the U.S. from a building owner's perspective, GSA contracted with the National Institute of Building Sciences (NIBS). NIBS was authorized by the U.S. Congress in the Housing and Community Development Act of 1974, Public Law 93-383. NIBS is a non-profit, non-governmental organization with a public interest mission to improve the building regulatory environment, facilitate the introduction of new and existing products and technology into the building process, and disseminate nationally recognized technical and regulatory information. Through NIBS, Congress established a public/private partnership to enable findings on technical, building-related matters to be used effectively to improve government, commerce, and industry.

NIBS and GSA convened a panel of industry experts comprised of representatives from manufacturers, installers, code officials, standards organizations, and building owners and operators, such as public transit, to participate in the study effort. The study evaluated the application of intermittent escalator technology in the U.S., addressing cost differentials and energy savings, as well as life safety, liability, and litigation concerns. Both new construction and retrofit of existing installations were included in the analysis. This document serves as the GSA report to Congress resulting from the study.

The Act defines "intermittent escalator" to mean an escalator that remains in a stationary position until it automatically operates at the approach of a passenger, returning to a stationary position after the passenger completes passage. ¹ In accordance with the Act, the study must include an analysis of cost savings derived from energy savings and reduced maintenance requirements and other issues as GSA deems appropriate.

Prior to passage of the Energy Policy Act, legislation had been introduced that would have required any escalator being installed in a federal building to be an intermittent escalator.² The law, as passed, requires the study, but not the use, of

¹ Public Law 109-58, Sec. 138 Intermittent Escalator Study, August 8, 2005.

² H.R. 4995, July 22, 2004, and H.Amdt.77, April 21, 2005, introduced by Rep. Louise M. Slaughter (D-NY-28).

intermittent escalators. At the present time, building codes in the U.S. do not permit the use of intermittent escalators. GSA issued a Fact Sheet on this topic in May of 2005, which noted that use of intermittent escalators is prohibited by code. (Appendix

Codes

The American Society of Mechanical Engineers (ASME) sets the industrial and manufacturing codes and standards that govern the public safety of elevators and escalators.3 ASME A17.1 "Safety Code for Elevators and Escalators" states in its preface, "Safety codes and standards are intended to enhance public health and safety." The application of this code extends to all areas of the vertical transportation industry. Other U.S. code-developing organizations, such as the International Code Council (ICC) and the National Fire Protection Association (NFPA), defer to ASME A17.1 for escalator design and construction standards. The GSA's "Facility Standards for the Public Buildings Service" (PBS-P100) incorporates ASME A17.1 as the basis for escalator design in its capital construction projects.

The American Public Transportation Association (APTA) develops transit system standards, which include the "Elevators and Escalators Technical Forum: Heavy Duty Transportation System Escalator Design Guidelines." These recommended practices and guidelines for escalators in the transit environment also incorporate ASME A17.1 for escalator safety design.

The use of intermittent escalators has been prohibited by ASME A17.1 since 1988. Specifically, ASME A17.1 prohibits both variation in speed⁴ after the start-up of an escalator and automatic starting or stopping.⁵ Shown below are revisions to the code due to accidents to passengers that resulted from an escalator changing speed when passengers were on the steps:

- Start switches either key operated or in a locked box, 1925
- Start switches to be key operated and within view of the steps, 1955
- Remote stop buttons prohibited, 1983
- Automatic starting prohibited, 1988
- Speed not varied after start-up, 1996
- Start switch must be returned to the start position before restarting, 2000

While there have been seven proposals to the standards committee to permit the use of intermittent escalators, 6 the committee has not reached a consensus on the use of intermittent escalators. Action on the most recent ballot has been tabled pending a review of the outcome of this study.

Founded in 1880 as the American Society of Mechanical Engineers, today's ASME is a 120,000-member professional organization focused on technical, educational and research issues of the engineering and technology community. ASME conducts one of the world's largest technical publishing operations, holds numerous technical conferences worldwide, and offers hundreds of professional development courses each year. ASME sets internationally recognized industrial and manufacturing codes and standards that enhance public safety. http://www.asme.org.

ASME A17.1 - 6.1.4.1 Limits of Speed. The speed attained by an escalator after start-up shall not be intentionally varied. ASME A17.1 - 6.1.6.1.1 Automatic Operation. Automatic starting by any means, or automatic stopping, except as required [in an

emergency], shall be prohibited.

See Appendix B, TN02-2375(TR01-22)(Esc&MW) Proposed Revisions to ASME A17.1-2004, Requirements 6.1.4 and 6.2.4.

Technology

Since intermittent escalators are not in use in the U.S. at the time of this study, the panel looked to the international escalator manufacturers⁷ to provide information on the technology of these machines as used in Europe, Asia, and in North America in Canada.⁸ Intermittent escalators have been permitted by code and operated in Europe⁹ since the 1980s and in Canada since the mid-1990s.

The Energy Policy Act defines an intermittent escalator as one that starts and stops; however, that is no longer the industry standard. Based on use of intermittent escalators in Europe, Asia, and Canada, the manufacturers do not recommend that the escalator come to a complete stop, but that standby or sleep mode be used. ¹⁰ Today, the industry standard is to reduce the escalator speed to sleep mode, when no passengers are riding, and bring the escalator up to full speed when a passenger approaches. The reduced speed of sleep mode varies by manufacturer and may be governed by local codes. The maximum operational speed of the escalator is governed by the ASME A17.1.¹¹

In their request to ASME for revisions to A17.1 to permit intermittent escalator use in the U.S., the industry provided the following description of the newest technology for intermittent escalators.

In the past it was not possible to precisely control the acceleration and deceleration rate of escalators and moving walks. However, variable voltage variable frequency motor controllers developed over the last 15 years can very precisely control the speed of AC motors used for escalators and moving walks so that the desired rate of speed change is never exceeded even for a fraction of a second. At an acceleration of 1.0 ft/sec2 it takes only 1.5 seconds to accelerate the escalator or walk from 10 fpm to 100 fpm. The normal application is to place a sensor station a few feet in front of the unit. The sensor is a [] device that signals to the controller when riders are approaching the escalator or moving walk. If during off-peak hours no persons have passed the sensor station and ridden on the unit for a certain period the controller will decide to lower the speed to 10 fpm. This deceleration will be completely controlled by the variable voltage variable frequency motor speed control so that the 1.0 ft/sec² deceleration rate will never be exceeded. The escalator or moving walk will continue to operate at 10 fpm until a person approaches the unit and the sensor is activated. The controller will then accelerate the unit at 1.0 ft/sec² so that the full operating speed of 100 fpm is achieved before the rider actually boards the escalator or moving walk. The operation of the sensors is completely interlocked so that the operating direction can never be reversed until the unit is stopped using the stop button and restarted in the opposite direction using the starting keyswitch as is done normally for all escalators and moving walks.12

⁷ The five largest international escalator manufacturers participated in this study: Fujitec (Japan), KONE (Finland), Otis (U.S.), Schindler (Switzerland), and ThyssenKrupp (Germany).

⁸ Intermittent escalators were permitted in Canada prior to harmonization of the Canadian and U.S. codes in 2002.

⁹ BS EN 115:1995, Safety rules for the construction and installation of escalators and passenger conveyors, Section 14.2 Controls governs the automatic starting and stopping of escalators.

When an escalator is completely stopped, potential passengers may be confused, not knowing if it is out of service or if it will start upon their approach. Additionally, start and stop operation increases wear and tear on the operating mechanisms.

There is no requirement in ASME A17.1 regarding the minimum speed of the escalator.

¹² From the NEII proposal for a technical revision to ASME A17.1-2000, 6.1.4 and 6.2.4, May 18, 2001, TR 01-22. (Appendix B) Note: Sensor devices vary by manufacturer. The manufacturers are asking for a code change that is descriptive, not prescriptive, of sensor devices.

The panel based its discussions and analysis of the intermittent operation of an escalator on the technology as described above, except that the speed of sleep mode was set at a conservative assumption of 20 feet per minute (fpm) for the purposes of the energy calculations and safety discussion. The intermittent escalator on which this study is based would have an operating speed of 100 fpm, which is the maximum speed currently allowed by ASME A17.1 (earlier editions of the code limited the maximum speed of escalators to 125 fpm).

Manufacturers and owner/operators in the group noted that retrofit of conventional to intermittent escalators may be facilitated by the fact that variable voltage, variable frequency motor controllers are installed on many escalators in service today. These motor controllers are useful during maintenance of the escalator and allow soft starts which save energy, as well as wear and tear on the motors and operating parts.

The Study

This study on the use of intermittent escalators looked at the potential for applying this technology in the U.S., addressing cost differentials and energy savings, as well as life safety, liability, and litigation concerns. The benefits of energy savings, lower life cycle expenses, and the perception of building green¹³ are valuable to building owners and operators. The potential safety risks with increased insurance costs and the threat of litigation are the biggest threats to building owners.

Collecting data for this study proved to be difficult. Since intermittent escalators are not permitted by the building codes in the U.S., there is no available data specific to intermittent operation using variable voltage, variable frequency motor controller technology in this country.

Data on intermittent escalator use in Asia and Europe were also difficult to obtain. A Japanese article was found on intermittent and dual speed escalators written by or for the manufacturer. ¹⁴ No data was available from the manufacturers or government agencies contacted in Asia, specifically in Hong Kong and Singapore.

The manufacturers ascribed use of intermittent escalators in Europe to the very high (relative to the U.S.) cost of energy there. Theoretical energy savings calculations were found, ¹⁵ but only one actual study on energy savings ¹⁶ was found by the panel and it was written for a manufacturer. It was the consensus of the manufacturers that the Europeans value any energy savings and that has led to the use of intermittent escalators there. While there are articles on the theory of escalator energy consumption, no peer-reviewed studies specifically on intermittent escalators using variable voltage, variable frequency motor controllers were found.

Intermittent escalators have been used in Canada since the mid-1990s and there are some data, albeit anecdotal, from the building owners and operators there. Letters and comments from Canadian building owner/operators used in this study are included in the National Elevator Industry, Inc. (NEII) code revision proposal to ASME in Appendix B.

The escalator panel of experts determined that the two most important elements for a thorough study were:

- A traffic study to measure the amount of time an escalator ran without passengers so that the standby or sleep mode time could be determined and energy savings could be calculated.
- A risk/benefit analysis to balance the risks to passenger safety with the energy and operational cost savings to the owner.

¹³ Green building is the practice of increasing the efficiency with which buildings and their sites use and harvest energy, water, and materials, and reducing building impacts on human health and the enfironment, through better siting, design, construction, operation, maintenance, and removal—the complete building life cycle. http://en.wikipedia.org/wiki/Green_building

¹⁴ Kawamoto, Hitoshi, Yoshio Ogimura, Koji Sugiura, Masato Yoshida. "Universal Escalator." Presented at Elevcon Helsinki 2006, discussing the KindMoverTM Escalator for the Toshiba Elevator and Building Systems Corp., Japan.

Al-Sharif, Lutfi. "The General Theory of Escalator Energy Consumption." Lift Report (May/June 1997) and reprinted in Elevator World (May 1998): 74.

¹⁶ Lichtenberg, Michael. "ACVF Drives and Remote Monitoring of Escalators." Schindler Lifts and Escalators Ltd., Vienna, Austria.

According to the manufacturers and ASME, the biggest unknown for this study was the traffic pattern for escalator use. Every escalator application is different. No traffic studies were available, according to NEII, the leading trade association, from any associations regarding escalator use in the U.S. or from European agencies where intermittent escalators are used.

The industry expert panel decided that the best approach for this study would be to evaluate an escalator most likely to produce energy and life cycle cost savings. The panel determined that if this "best case" scenario produced only limited energy savings then there was little to be gained from the evaluation of other escalators with heavier usage patterns. The panel found that it would be most appropriate to assess an escalator application that would provide a significant result. For example, the panel evaluated inclusion of commercial applications, such as the Ronald Reagan Federal Building in Washington, DC, which is a mixed use office/commercial property, as well as transit station escalators. The panel reached consensus that the escalator presenting the greatest potential for analysis of cost savings and availability for study was a Washington Metropolitan Area Transit Authority (WMATA or Washington Metro) escalator in a station where the daily traffic fluctuates from moderate/heavy, at certain times of the day, to minimal, with period of very little use. A commercial application like the Reagan Building would not provide sufficiently differentiated traffic usage throughout the day. The panel found that escalators that were in near-constant use would be less likely to yield energy savings, since there would be fewer periods of lighter usage during which time the escalators would potentially go into an energy saving mode.

A subcommittee of the industry expert panel designed and conducted an escalator traffic pattern study (Appendix C). The subcommittee was comprised of RSMeans, ¹⁷ a prominent construction cost estimating publications firm; KONE, an escalator manufacturer; and Washington Metro, one of the largest owner/users of escalators in the U.S. The traffic study was presented to the industry expert panel for analysis. Energy and life cycle cost analyses were performed by RSMeans based on the information collected during the traffic study and evaluations by the panel.

The panel collected safety information from available data using code, insurance, and litigation records and other accident data sources. It was difficult to obtain detailed accident information due to litigation, privacy, and non-disclosure concerns. Ultimately, the comments on safety are derived from interviews and round-table discussions with consultants, safety authorities, and owner/operators and are based upon their first-hand, industry expert experiences.

Energy and Life Cycle Cost Analyses

The National Institute of Building Sciences commissioned from RSMeans a Life Cycle Cost (LCC) Study¹⁸ for intermittent escalators.¹⁹ Neither the traffic pattern for potential use nor the financial feasibility of intermittent escalators has been studied in the U.S., primarily due to the ASME A17.1 prohibitions on automatic start/stop and

RSMeans is North America's leading supplier of construction cost information. A product line of Reed Construction Data, RSMeans provides accurate and up-to-date cost information that helps owners, developers, architects, engineers, contractors and others to carefully and precisely project and control the cost of both new building construction and renovation projects.

The LCC Study used "present value" calculations in accordance with Code of Federal Regulations (CFR), Title 10, Part 436, Subpart A: Program Rules of the Federal Energy Management Program.

The life cycle economic analysis does not include any architectural and engineering design or construction modifications to the existing escalator or the surrounding space. Since all building layouts are different, each intermittent escalator application must be evaluated individually.

variable speed that prevent the use of intermittent escalators in the U.S. RSMeans collected and included the following data in the LCC Study:

- Escalator Traffic Study (Appendix C)
- Initial construction cost data
- Preventive maintenance and repair cost data
- Inflation
- Interest rates

The Energy Policy Act defines the term "intermittent escalator" as an escalator that remains in a stationary position until it automatically operates at the approach of a passenger, returning to a stationary position after the passenger completes travel. However, the expert panel evaluated two intermittent options, namely "shut down" and "slow down" modes. Escalator manufacturer representatives provided first-hand information from experiences their organizations encountered in intermittent use applications in Asia, Europe, and Canada. The consensus of the industry expert panel was that "slow down" mode is the preferred energy saving method, primarily because "shut down" suggests to the approaching user that the escalator is out-of-order, so that users do not approach the escalator to trigger the sensors that turn on the escalator. For that reason, "shut down" intermittent escalators do not serve their intended purpose. Secondarily, stopping and starting involves greater safety risks and more wear and tear on the equipment as it accelerates from a stopped position to an operating speed of 100 fpm in a matter of seconds. According to the manufacturers, Asian, European, and Canadian intermittent escalators operate in "slow down" mode rather than "shut down" mode. As a result, this report extends the definition of intermittent operation to include "slow down." The panel determined that the LCC study would be based upon a slow-down speed of 20 feet per minute.

As a means to obtain actual usage data on an intermittent escalator, the panel determined that it would evaluate an escalator with a high potential for intermittent use throughout the day. The panel further determined that a heavily trafficked Washington Metro escalator would provide the best observation results and identified the subjects of the study as one Up and one Down escalator at the Washington Navy Yard, WMATA station. These escalators were selected for inclusion in the study, because this particular station is known by the WMATA engineers who participated on the panel to have significant activity in the morning and afternoon rush hours but little activity during the day. The results of the calculations presented in the LCC Study are likely indicative of other WMATA stations, as well as commercial sites with similar traffic patterns, though, as previously stated, only an actual traffic study on each specific escalator location will reveal the energy savings potential for that escalator.

An analysis of the data revealed that the traffic characteristics are the largest determining factor in energy costs. The WMATA Navy Yard escalators operate a total of 135 hours per week. (There are a total of 168 hours per week, or 7 days x 24 hours/day.) The traffic study showed that the Up escalator could be operated in slow-down mode 110.7 hours and the Down escalator could be operated in slow-down mode 95.9 hours per week. The WMATA escalators studied actually operate 7020 hours per year and have a total average potential slow-down time of about 5400 hours, or about 77 percent. (See Appendix C, Navy Yard Station Escalator Traffic Study.) Based on the traffic study and energy costs, for WMATA, this would yield approximately \$1800 per year in potential electrical energy savings for the slow-down Up escalator and \$1600 per year for the Down escalator. These savings are based on the traffic study escalator usage data, manufacturer data on escalator electrical usage in standard and slow-down mode, and the electricity rates actually paid by WMATA.

Four of the five leading escalator manufacturers for the U.S. market (all five participated in the study) provided data on escalator life for standard use and their best, professional estimate of extended life for slow-down use. The information revealed that a clear advantage emerged for slow-down escalators. While an exact extension of useful life for slow-down escalators could not be quantified and no measured data could be found, all industry experts agreed that there would be some increase in the life of the escalator.

The next step in the process was to gather cost and technical data for the financial analysis. This study analyzes the LCC for both new installations and retrofitting existing escalators. Data required included the following:

- New escalator material, labor, and equipment costs
- Escalator retrofit cost for standby operation
- WMATA energy costs
- Escalator power requirements
- Preventive maintenance and ordinary repair costs
- Abuse repair costs
- Escalator life

The above information was obtained from industry consultants, escalator manufacturers, PEPCO (Potomac Electric Power Company), 20 and WMATA. The estimated material, labor, and equipment cost to install a new WMATA unit with 13 feet of vertical lift powered by a 7.5 HP 480v-3 phase motor is \$300,000. The additional cost to outfit a new unit for intermittent control is estimated at \$5500, and to outfit an existing unit for intermittent use is \$8300. By averaging estimates from the four leading manufacturers, RSMeans calculated that increases over base prices would be 1.85% for new construction and 2.76% for retrofitting.

Architectural design and construction requirements for the installation of an intermittent escalator in either new construction or an existing building retrofit would include the addition of building space at the entry and exit of the escalator, stanchions for sensors, railings to assure that escalator passengers trigger the sensors, additional signage, possible adjustments to avoid interference of escalator entry/exit with other circulation space requirements, and other concerns. The 8' of unobstructed space typically required at the end of an escalator may not be adequate for the distance required from the sensors to the comb-step intersection²¹ to accommodate acceleration of the escalator from 20 to 100 fpm and allow a passenger to step onto the escalator operating at normal speed.

In both new and retrofit applications, a substantial cost will be incurred to increase the space required to accommodate the distance from the sensors to the comb-step intersection for safe operation of the intermittent escalator. In the case of an 8' approach and exit to an escalator with a 4' tread and about 5' total width (typical in WMATA and many buildings), it would be necessary to add approximately 80 square feet of building space dedicated to the intermittent escalator platform. At a typical cost in the range of \$125-\$300 per square foot, the cost of additional building space (roughly in the range of \$10,000-\$24,000) would far exceed the cost of the intermittent escalator controls. The cost to modify the existing structure could certainly be higher than new construction, considering the potential interference of greater platform requirements with other parts of the building, i.e., elevator lobbies, columns, fire exits, and corridor partitions. In many cases, the total cost of design and construc-

Transit authority electric rates are available on the PEPCO website, www.pepco.com, from which energy costs (which vary between summer and winter) can be calculated.

²¹ See Appendix B for a typical Plan and Section/Elevation of an intermittent escalator.

tion of new and retrofit applications could easily be higher than the energy savings gained from intermittent operation and there would be no financial justification to install an intermittent escalator. The cost for increased space for intermittent escalators could be prohibitive from a life cycle cost or cost effectiveness standpoint.

If it were essential that an intermittent escalator be installed as a retrofit in a space that was not adequate to provide the distance required from the sensors to the combstep intersection, the speed of the escalator could be adjusted so that the slow-down speed was greater than 20 fpm and the operating speed was less than 90 fpm. In which case, there would be less time required for the escalator to reach operating speed, requiring less distance from the sensors to the combplate. There would also be less energy savings, perhaps not enough to justify installation of an intermittent escalator. The expert panel did not make a recommendation to install an intermittent escalator where space does not permit.

Table 1, below, illustrates RSMeans' energy calculations.

Table 1: Energy Cost Calculations based upon PEPCO Data Energy Cost Calculation (in dollar per kWh)

| | June – October | November – May |
|-------------------------------------|----------------|----------------|
| Generation | \$0.10927 | \$0.10292 |
| Transmission | \$0.00138 | \$0.00138 |
| Distribution | \$0.00808 | \$0.00808 |
| Delivery Tax | \$0.00770 | \$0.00770 |
| Public SpaceOccupancy Surge | \$0.00154 | \$0.00154 |
| Reliability EnergyTrust Fund Credit | -\$0.00065 | -\$0.00065 |
| Generation ProcurementCredit | -\$0.00002 | -\$0.00002 |
| Energy Charge | \$0.12730 | \$0.12095 |
| | | |

The energy costs were then utilized to project potential energy savings for each escalator. The manufacturers provided kilowatt usage (kWh) for their motors as well as estimated percentage energy reductions based upon standby operation. The projected energy costs for slow-down were compared with traditional operating costs as shown in Table 2.

As a result, RSMeans determined that energy savings for the Up escalator would amount to \$1800 per year and for the Down escalator, \$1600 per year. The derivation of savings for Table 2 are shown in the Appendix D spreadsheets.

Table 2: Energy Cost Savings
Table 2A: Energy Usage for UP Escalator Intermittent /
Slow-Down Operation

| Billing | g Months | Sub-Total Week Billing Season | UP Escalator Standby (Hr/Yr) | Energy Savings (kWh) | Energy Savings (\$0.12730/ kWh) |
|---------|-----------|-------------------------------------|------------------------------------|----------------------------|---------------------------------------|
| (| June | | | | |
| | July | | 1000000000 | | \$826.43 |
| Summer | August | 23 weeks | 2546 | 6492 | |
| | September | | | | |
| | October | | | | |
| Billing | g Months | Sub-Total Week Billing Season | UP Escalator Standby (Hr/Yr) | Energy Savings (kWh) | Savings (\$0.12095 per kWh) |
| | November | | | | |
| | December | | | | |
| | January | 2000 | 0.00000 | 8186 | \$990.10 |
| Winter | February | 29 weeks | 3210 | | |
| | March | | | | |
| | April | | | | |
| | May | | | | |
| | | 52 weeks | 5756 hours | 14678 kWh | |
| Yearly | Savings | | | | \$1,816.53 |

Approximate Savings \$1800/year

Notes:

- 1. Estimate an energy saving between 2.2kW and 2.9kW when running at standby speed to full speed, which translate as energy savings were approximately between 40% and 52%, RSMeans using 2.55 kW to estimate energy savings.
- 2. Formulae for energy savings: UP Escalator (2.55 kW) x (\$ rate) x (110.7 hr/wk) x (52 wk/yr)

Table 2B: Energy Usage for DOWN Escalator Intermittent / Slow-Down Operation

| Billin | g Months | Sub-Total Week Billing Season | UP Escalator Standby (Hr/Yr) | Energy Savings (kWh) | Energy Savings (\$0.12730/ kWh) |
|---------|-----------|-------------------------------------|------------------------------------|----------------------------|---|
| | June | | 32 12 G | | |
| | July | | 23 weeks 2206 | 5625 | \$716.06 |
| Summer | August | 23 weeks | | | |
| | September | | | | |
| | October | | | | |
| Billing | g Months | Sub-Total Week Billing Season | UP Escalator Standby (Hr/Yr) | Energy Savings (kWh) | Energy Savings (\$0.12095 per kWh) |
| | November | | | | 76.50 |
| | December | | | | \$857.78 |
| | January | | | | |
| Winter | February | 29 weeks | 2781 | 7092 | |
| | March | | | | |
| | April | | | | |
| M | May | | | | |
| | | 52 weeks | 4987 hours | 12717 kWh | |
| Yearly | Savings | | | | \$1,573.84 |

Approximate Savings \$1600/year

Notes:

- 1. Estimate an energy saving between 2.2kW and 2.9kW when running at standby speed to full speed, which translate as energy savings were approximately between 40% and 52%, RSMeans using 2.55 kW to estimate energy savings.
- 2. Formulae for energy savings: DOWN Escalator (2.55 kW) x (\$ rate) x (95.9 hr/ wk) x (52 wk/yr)

A Life Cycle Cost advantage emerged for intermittent escalators, whether as new construction or as a retrofitted conventional escalator. The average life for new escalators would be extended; however, the exact length of time is undetermined.

Maintenance costs were provided to the panel by WMATA. The preventive maintenance and ordinary repair costs for the escalators are \$3850 per month. An additional \$350 is budgeted for repairs due to abuse. As the estimated standby time is approximately 77% for escalators utilizing the slow-down mode, it was estimated by consensus of the industry experts in this study that preventive maintenance and repair costs could be reduced by 2%, i.e., from \$3850 to \$3773 per month.

The escalator manufacturers estimated escalator life based on standard and intermittent slow-down operation. Table 3 illustrates how the data was used to calculate the present worth of the Up and Down escalators in traditional and intermittent operation.

Table 3: Escalator Life Cycle Cost Analysis

| | New Esc | alator | Retrofit 10 year | old Escalator |
|---|-------------|-------------|------------------|---------------|
| Description | Up | Down | Up | Down |
| A. LCCA Input Data A1. Financial Criteria Input A1.1 Nominal Discount Rate "d" = 4.6%, 1.6% Inflation A1.2 Energy Escalation Rate per DOE forcast included in BLCC5 Program A1.3 Maintenance Labor x Parts Escalation + 1.6% per BLCC5 Program A1.4 Study period "n" = 25 years new and 15 years retrofit A1.5 Life Cycle of escalator systems - 25 years new and 15 years on an existing 10 year old unit Note: The life cycle of conventional and intermittent elevators are assumed equal in the study though intermittent systems should have their life cycle extended. | | | | |
| A2 Cost Data input | | | | |
| A2.1 Investement Costs Initial cost - base year lo | \$5,550.00 | \$5,550.00 | \$8,300.00 | \$8,300.00 |
| A2.2 Operational Cost Savings Ao | \$2,724.00 | \$2,524.00 | \$2,724.00 | \$2,524.00 |
| A2.2.1 Energy savings - annual - Ao | \$1,800.00 | \$1,600.00 | \$1,800.00 | \$1,600.00 |
| A2.2.2 Maintenance Savings - Annual Ao | \$924.00 | \$924.00 | \$924.00 | \$924.00 |
| BLCCA Summary | | | | |
| B1 PV Investement Costs (PV Factor 1.0) | \$5,550.00 | \$5,550.00 | \$8,300.00 | \$8,300.00 |
| B2 PV Operational Cost Savings | \$44,555.00 | \$41,392.00 | \$30,424.00 | \$28,269.00 |
| B2.1 Energy (A2.2.3 x UPV# - 19.75) .800 x 19.75 | \$28,465.00 | \$25,302.00 | \$19,393.00 | \$17,238.00 |
| B2.2 Maintenance (A2.2.3 X UPV# - 17.38) with 1% inflation | \$16,090.00 | \$16,090.00 | \$11,031.00 | \$11,031.00 |
| B3 Evaluation Measures (ASTM Standards) | | | + | |
| B3.1 NS - Net Savings (B2 - B1), if nagative, won't pay for itself | \$39,005.00 | \$35,842.00 | \$22,124.00 | \$19,969.00 |
| B3.2 SIR - Savings to Investment Ratio (B2 + B1) | 8.0 | 7.5 | 3.7 | 3.4 |
| B3.3 AIRR - Adjusted Internal Rate of Return (V=Reinvestment rate = d = 5%) | 11.95% | 11.62% | 8.49% | 8.17% |
| B3.4 Simple Payback Period without Maintenance Savings- Years | 3.1 | 3.5 | 4.6 | 5.2 |
| B3.4.1 SPB - Simple payback including maintenance savings - Years | 2.04 | 2.2 | 3.05 | 3.29 |
| B3.4.2 DPB - Discounted Payback - Years, something less than 5 years, | 2.21 | 2.39 | 3.39 | 3.67 |

Notes

General: All percent value factors and calculators are based on a nominal rate of interest and in accordance with ASTM Building Economics Standards.

Specific:

A2.2.1 Energy cost savings are based on \$0.1273/kwh

A2.2.2 Maintenance cost savings are based on a 2% reduction of conventional escalator maintenance costs of \$3.850/month or \$46,200 annually.

Additional conclusions about financial impacts for the specific WMATA escalators analyzed in this study include the following:

- The payback period on the \$5500 cost for the sensors and motor control unit only—not including the approximate \$10,000-\$24,000 for design and construction costs—for a new Intermittent Escalator installation is 3.1 years for an Up escalator and 3.5 years for a Down escalator. If these additional design and construction costs are included in the payback period calculation, the payback period would be significantly longer.
- To retrofit standard conventional escalators the payback time for the \$8300 cost for sensors and motor control unit only—not including the approximate \$10,000 -\$24,000 for design and construction costs—is higher, at 4.6 years for an Up escalator and 5.2 years for a Down escalator. If these additional design and construction costs are included in the payback period calculation, the payback period would be significantly longer.
- The adjusted Internal Rate of Return for the sensors and motor control unit only—an initial investment cost of \$5500 for new and \$8300 for retrofit—is 11.95% for an Up escalator and 11.62% for a Down escalator. The Internal Rate of Return calculations do not include design and construction costs, which would significantly reduce the return rate. Actual design and construction costs would vary for each particular installation and could only be determined on a case-by-case basis at each specific escalator location.
- The Reinvestment Rate for the sensors and motor control unit only—an initial investment cost of \$5500 for new and \$8300 for retrofit—is 5%. As with the Internal Rate of Return calculations, the Reinvestment Rate calculations do not include design and construction costs, which would significantly reduce the return rate. Actual design and construction costs would vary for each particular installation and could only be determined on a case-by-case basis at each specific escalator location.

Recalling that the WMATA escalators studied actually had a total average standby time of 77 percent, these findings should be weighed against the approximately \$1800 per year in potential electrical energy savings and reduced maintenance costs to be realized through the use of intermittent escalators. The savings would be more significant for entities or owner/operators with a substantial inventory of escalators in use. 22

If the standby time is reduced, as would be the case for escalators that carry passengers more frequently than the WMATA units in this study, the energy and maintenance savings would decrease, thus lengthening the payback period for the intermittent monitor/control costs. The LCC calculations shown on the spreadsheets in Appendix D indicate that, if the energy savings is reduced to \$1000 per year and the maintenance is reduced to zero based upon less slow-down time, discounted payback on the intermittent monitor/control costs alone, exclusive of any design and construction costs, would occur at 6.78 years. The \$1000 in energy savings per year would equate to a slow-down time of 45%. Seven years is often considered the maximum attractive payback time for commercial investment; therefore, an escalator with less than 45% slow-down time would not be considered economical for intermittent operation. NOTE: None of these LCC calculations considers the cost of related design and construction accommodations for an intermittent escalator installation.

WMATA conservatively estimates that 25% of the 588 escalators they operate, or 147 escalators, would have usage patterns similar to the escalators studied. With an average energy savings and reduced maintenance cost of \$1800 each, 147 escalators enabled to operate in slow-down mode could save WMATA \$264,600 annually.

LCC calculations were not done on the architectural/construction costs since each application is different.

Risk/Benefit Analysis

A true risk/benefit analysis is beyond the scope of this study. The industry expert panel does not have the expertise to fully evaluate the risks and costs of human injury. This study has provided a mechanism to calculate the benefits of energy and life cycle cost savings, in accordance with the Act. The ASME contributed information to this study based on presentations to the A17.1 Escalator and Moving Walk Committee by experts in human engineering studies (Appendix E); however, a more thorough evaluation commissioned through an organization such as ASME, of the safe use of intermittent escalators, than the information gathered and reported below, would likely produce more conclusive findings of risks.

The industry panel reviewed the safety concerns listed below, which have been brought to the attention of the ASME A17.1 Escalator and Moving Walk Committee. These concerns are quoted directly from information provided by the ASME.

- Varying escalator speed will increase the accident rate of trips/falls.
- A variation in the rate of speed of even 1.0 ft/sec² is not completely safe for riders.
- Blind or disabled persons would likely trip or fall as they stepped off an escalator that was moving at a faster speed (than it was moving when they stepped on).
- Someone could step off the escalator as it is accelerating.
- The escalator should have a sign "Caution Speed May Vary" to provide a warning for the possibility that the escalator may change speed with someone on it.
- There should be a means to monitor the presence of a passenger on the escalator so that speed does not change while people are on the unit.
- There is the additional risk of equipment failure, more sensors are required to detect passengers; therefore, there are more sensors to fail.

The industry expert panel noted the following three paragraphs, which represent the safety concerns of several prominent experts in this field.

- It is essential that escalator speed does not vary while carrying a passenger.
 Intermittent operation requires that the escalator be equipped with a variable speed control that will slow it down when there is no demand and then resume full speed when required by the arrival of a passenger.
- With intermittent operation, a person approaching the escalator must be detected by a sensor and a mechanism must be triggered to bring the escalator up to full speed before the person reaches the moving steps, which requires additional dedicated space between the sensor and the comb-step intersection of the escalator. The detection system must be such that people cannot circumvent it and still be able to board the escalator. The system must also protect against its own failure. Monitoring passengers, so that the escalator reverts back to the reduced speed only after all those who boarded are off the moving steps, is very difficult to accomplish. Past methods used for automatic starting and stopping permitted the escalator to operate at full speed for 1.5 to 2 times the time it takes for a passenger to enter onto the moving steps, ride the length of the escalator, and step off. This feature was responsible for most of the accidents attributable to automatic start and stop escalator operations that were reported by manufacturers, owners, and operators.

²³ David L. Steel, escalator consultant and Chairman of the A17.1 Escalator and Moving Walk Committee, presentation on safety to the expert panel.

• Experience, human factors, and physics all indicate that people traveling on their feet in a horizontal direction do not respond well to changes in the velocity of the platform on which they are standing. In spite of moving handrails and caution signs advising passengers to hold the handrail and face forward, every year the most common accident passengers experience on a moving escalator is a fall. Some are the result of an escalator stopping, but many are the result of people losing their balance when they become disoriented for various reasons. The fact that they are traveling on an incline is sufficient to produce illusions about the angle, speed, length, and other attributes of the escalator. Even a gradual change in speed can produce adverse reactions in some passengers that may lead to a fall. Passengers expect and anticipate that an escalator will move at a constant speed and will not change speed or stop. The industry's experience with automatic starting and stopping escalators, until they were prohibited, illustrated this effect.²³

As with all escalators, accidents on intermittent escalators are far more likely if riders do not use them as intended. The intended use of intermittent escalators is somewhat more restrictive than conventional escalators. For instance, riders who intentionally avoid triggering the sensors could experience the acceleration of the escalator from slow-down speed to operational speed while they are on the unit, thus putting themselves at risk of an accident.

Collecting information on escalator accidents, injuries, and fatalities proved to be difficult. Certainly, no safety data on intermittent escalator use in the U.S. is available. There is also very little data on the exact cause of escalator accidents. The U.S. Consumer Product Safety Commission (CPSC) maintains numbers on accidents occurring on or near escalators, but it is very difficult to decipher from these reports what specifically caused the accidents. The data available is from victims and is subject to human error. However, the CPSC proved to the best available source of injury data. The NEII, manufacturers, and owners either do not have or do not release records on accidents. The Federal Transit Administration (FTA) through the National Transit Database (NTB) collects data on accidents, but was unable to provide information specific to escalator accidents.

A search of escalator related injuries from 1/1/98 - 5/30/06, conducted by the CPSC on June 1, 2006, provided information on accidents and injuries attributed to uncontrolled escalator speed changes. ²⁴ There were about 3000 escalator incidents involving falls or entrapments in the database. Of the five deaths associated with escalators, none mentioned speed or speed changes as a cause or contributing factor.

While the data shows that most injuries on escalators are due to falls, a relatively small number of these injuries are attributed to escalator speed change. There was no data found to prove or disprove that intermittent operation would be any more—or less—hazardous than conventional operation. According to one industry expert, "The low frequency of escalator accidents makes it difficult to easily determine the effectiveness of changes in escalator design..." 25

²⁴ The CPSC system includes Death Certificates (DTHS) from State Vital Statistics agencies, Injury and Potential Injury Incidents (IPII), Indepth Investigations (INDP) and the National Electronic Injury Surveillance System (NEISS). The search was conducted by Michael Greene, PhD.

²⁵ Fruin, John J., "Escalator Safety, An Overview." *Elevator World* (August 1988): 48.

²⁶ Email from Dave Turner for Curtis Forney, NAVTP Executive Director.

²⁷ Locations where intermittent escalators are in use include: The TELUS Convention Centre and the Calgary Airport, Calgary, Alberta, and the Vancouver International Airport, British Columbia.

The National Association of Vertical Transportation Professionals (NAVTP) offered the following comments on safety.

There is no accident data that can be collected that would show that utilizing this operation would increase the risk of riding on an escalator any more than the addition of any other feature on the escalator over the last 85 years would increase the risk of riding the escalator. Every feature added increases the probability of that feature or device failing and causing the escalator to behave in an unusual manner.²⁶

Reports from Canada,²⁷ where intermittent escalators have been operational for nearly a decade, claim no injuries as a result of these operational characteristics. (Appendix B)

In telephone interviews with retail store and shopping center representatives, the panel found that litigation—the possibility of litigation and the certain high cost of litigation—was the primary reason owners had limited interest in intermittent escalators. The expert opinion of the panel was that because litigation costs are so great in the U.S., they would outstrip any possible owner-perceived benefits such as energy savings. The cost of an accident would need to be weighed against the potential energy savings. Moreover, the leading escalator manufacturers unanimously agreed that they would be unlikely to pursue a contract to install or maintain intermittent escalators or to bid upon such work in the U.S. due to liability and litigation concerns.

Study Findings

- 1. The WMATA escalators studied, if in intermittent operation would—
 - Operate at slow-down speed 77% of the time.
 - Produce an Annual Energy Cost Savings of \$1600 for the Down escalator and \$1800 for the Up escalator.
- 2. Maintenance cost savings are estimated at a 2% reduction of conventional escalator maintenance, a savings of \$924 annually per escalator.
- Escalators, if in intermittent operation might have a moderate average life extension beyond the estimated life of 25 years for new, properly maintained escalators.
 The exact length of time is undetermined.
- 4. Payback period to install the controls that make escalators intermittent—
 - New Escalators—the \$5500 cost for the sensors and motor control unit only
 does not include the approximate \$10,000-\$24,000 for design and
 construction costs—3.1 years for Up and 3.5 years for Down. If these
 additional design and construction costs are included in the payback period
 calculation, the payback period would be significantly longer.
 - Retrofitted Escalators—the \$8300 cost for the sensors and motor control unit
 only does not include the approximate \$10,000-\$24,000 for design and
 construction costs—4.6 years for Up and 5.2 years for Down. If these
 additional design and construction costs are included in the payback period
 calculation, the payback period would be significantly longer.
- 5. Internal Rate of Return for the sensors and motor control unit only—an initial investment cost of \$5500 for new and \$8300 for retrofit—is 11.95% for Up and 11.62% for Down. The Internal Rate of Return calculations do not include design and construction costs, which would significantly reduce the return rate. Actual design and construction costs would vary for each particular installation and could only be determined on a case-by-case basis at each specific escalator location.
- 6. Reinvestment Rate for the sensors and motor control unit only—an initial investment cost of \$5500 for new and \$8300 for retrofit—is 5%. As with the Internal Rate of Return calculations, the Reinvestment Rate calculations do not include design and construction costs, which would significantly reduce the return rate. Actual design and construction costs would vary for each particular installation and could only be determined on a case-by-case basis at each specific escalator location.

Study Conclusions

Based on the findings of this study the industry expert panel reports that -

- The energy and economic savings and rate of return on investment attributable to the use of intermittent escalators could be modest at best for intermittent/low use scenarios, and the overall savings could be significant only if employed broadly over a large inventory of escalators.
- 2. The cost to retrofit an escalator in an existing building was approximated to be between \$10,000 and \$24,000 assuming no significant structural or design issues. The actual construction cost would vary on a case-by-case basis. The flow of escalator passengers would need to be evaluated in any retrofit application, as would compliance with the Americans with Disabilities Act (ADA) and other applicable national codes and standards. Related design and construction costs to accomplish an appropriate retrofit for intermittent escalator capabilities could be significant depending on existing building conditions and space considerations.
- 3. Although insufficient data exists to confirm this conclusion, the use of intermittent escalators probably would not significantly decrease the safety of escalators if used properly and if available safety precautions were implemented. However, if used improperly, as occurs frequently on conventional escalators in all locations, intermittent escalators would likely elevate the potential safety hazards associated with falls on escalators.
- 4. The use of intermittent escalators has the potential to significantly increase the liability and in turn litigation attached to escalator use, primarily because of user perceptions of movement differential. Litigation due to falls on escalators is already costly. Manufacturers and installers may likely choose not to bid on or install intermittent escalators.
- 5. A risk/hazard analysis to document the safety of intermittent escalators is warranted. Such a study is best commissioned through an organization such as the American Society of Mechanical Engineers (ASME). The results of such a study would enable the ASME to conduct an accurate and balanced review of the adoption of code revisions to permit or to continue the prohibition of intermittent escalators in the United States.
- 6. The use of intermittent escalators in the U.S. would require a change to the ASME standards and building codes.

7. Other energy saving technologies, that do not require safety code revisions, are known to the manufacturers and merit study. These technologies are not compatible with intermittent escalator technology and were therefore beyond the scope of this report.

The industry expert panel concluded that, even if there were energy and economic savings and no discernible decrease in escalator safety, the potential for substantial liability costs in the present litigious climate will likely preclude the adoption and use of intermittent escalators in the United States.

Abbreviations and Acronyms

AC Alternating current

ADA Americans with Disability Act

APTA American Public Transportation Association

ASME American Society of Mechanical Engineers

BS EN British Standard European Standard (English version of

the Norme Européenne, Comité Européen de

Normalisation (CEN))

CFR Code of Federal Regulations

CPSC Consumer Product Safety Commission

FTA U.S. Department of Transportation Federal Transit

Administration

GSA U.S. General Services Administration

H.R. U.S. House of Representatives

ICC International Code Council

LCC Life Cycle Cost

NAVTP National Association of Vertical Transportation

Professionals

NEII National Elevator Industry Inc.

NFPA National Fire Protection Association

NIBS National Institute of Building Sciences

NTD FederalTransit Administration NationalTransit Database

NYCT New York City Transit Authority

PBS U.S. General Services Administration Public Buildings

Service

PEPCO Potomac Electric Power Company

WMATA Washington Metropolitan Area Transit Authority

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Appendix A



Background:

A House Bill amendment, authored by Congresswoman Louise M. Slaughter, would add language to the proposed "Energy Policy Act of 2005," requiring escalators installed in Federal Buildings be of the "Intermittent" type.

An Intermittent Escalator differs from conventional escalator designs in that it uses motion sensing or floor-pad switches to automatically turn an escalator "On" when someone approaches and "Off" when the escalator is not needed. This differs from current escalator designs in the United States, which provide for continuous operation, and require manual shut-off to assure passenger safety.

Discussion:

The exact text associated with the amendment is as follows:

Section 543 of the National Energy Conservation Policy Act (42 U.S.C. 8253) is amended by adding at the end the following new subsection:

(e) Intermittent Escalators-

- (1) REQUIREMENT- Except as provided in paragraph (2), any escalator acquired for installation in a Federal building shall be an intermittent escalator. (2) EXCEPTION- Paragraph (1) shall not apply at a location outside the United States where the Federal agency determines that to acquire an intermittent escalator would require substantially greater cost to the Government over the life of the escalator.
- (3) ADDITIONAL ENERGY CONSERVATION MEASURES- In addition to complying with paragraph (1), Federal agencies shall incorporate other escalator energy conservation measures, as appropriate.
- '(4) DEFINITION- For purposes of this subsection, the term 'intermittent escalator' means an escalator that remains in a stationary position until it automatically operates at the approach of a passenger, returning to a stationary position after the passenger completes passage.'
- Note that no reference was made in the proposed legislation about retrofitting
 existing escalators, but the amendment's language can be interpreted as applying
 when an existing escalator is replaced.

- Identified benefits of Intermittent Escalators include energy savings and reduced
 maintenance costs. However, there is conflicting opinion as to whether maintenance costs will be decreased or increased. The maintenance issue is uncertain as
 there should be a benefit of reduced gear/drive wear, but such is countered by
 concerns over additional controls maintenance.
- There are widespread safety concerns, expressed by GSA engineers, about Intermittent Escalator technology; as a faulty sensor might suddenly start or stop an escalator when loaded with passengers. This concern is shared within the industry, as reflected by the current International Building Code, which requires adherence to the American Society of Mechanical Engineers standard ASME 17.1 that states in Section 6.1.6.1.1, under Automatic Operation: "Automatic starting by any means, or stopping, except as required in 6.1.6 shall be prohibited." *The exception has to do with working on the escalator by trained repair or maintenance personnel only.*
- Although GSA is not required to adhere to industry codes, legislation mandates GSA to consider and use national building codes to the maximum extent possible. Whether GSA were to apply a national building code on this matter is somewhat irrelevant since GSA's own "Facilities Standards for the Public Building Service" independently stipulates escalator design adherence to ASME 17.1 standards.
- GSA has not pursued/applied Intermittent Escalators in any of its building designs. Our Region 2 office is aware that New York City is pursuing one such installation at Harold Square, but only after obtaining a code variance.
- Known manufacturers of Intermittent Escalators include KONE (formerly Montgomery) and Schindler. Otis and Mitsubishi did not respond to inquiries in the time allotted.
- Whether considering new construction or the replacement of existing escalators, the number of escalators that could be addressed by GSA's inventory is very small. GSA buildings seldom have occupancies that require large numbers of people to be transported between floors (i.e. beyond an elevator's capacity to respond), and GSA design criteria (within the "Facilities Standards for the Public Building Service") indicates that escalators should be used only when absolutely necessary, due to high maintenance costs (page 60).
- Although no exact figures were defined within the time allotted, life cycle cost benefit is not disputed. Annual energy savings per escalator is probably between \$3,500 and \$7,500, depending on a number of factors: At this rate, it would take a relatively short period of time to recapture premium costs associated with involved controls and drive mechanisms.

Conclusion:

This technology is currently not aligned with national codes, or GSA design criteria. While Intermittent Escalators are not disputed in terms of their economic merit, safety concerns need to be dismissed through well documented test cases. While it may be appropriate for the Federal Government to take risks in exploring such innovative technologies, it would not be appropriate to mandate the use of systems that are not code compliant.

Ultimately, widespread adoption of this technology will only be achieved with industry accepted changes to ASME 17.1.

Appendix B

ASME Code Revision Proposal

TR 01-22 Technical Revision ASME A17.1-2000, 6.1.4 and 6.2.4 Variation of Speed

1) Reason for the Proposal

Public facilities such as airports are open 24 hours per day but the number of persons using the facility is greatly reduced during certain off-hour periods of the day. To reduce maintenance requirements and lower energy costs these facilities desire to run their escalators and moving walks at lower speeds during these low traffic periods. Most wear of escalator and moving walk parts is related to the number of cycles of operation and therefore running at a lower speed reduces the wear of the rollers, chains and machinery components. Facilities that are in operation 24 hours per day want to reduce their maintenance downtime to an absolute minimum.

2) New Technology

In the past it was not possible to precisely control the acceleration and deceleration rate of escalators and moving walks. However, variable voltage variable frequency motor controllers developed over the last 15 years can very precisely control the speed of AC motors used for escalators and moving walks so that the desired rate of speed change is never exceeded even for a fraction of a second. At an acceleration of 1.0 ft/sec2 it takes only 1.5 seconds to accelerate the escalator or walk from 10 fpm to 100 fpm. The normal application is to place a sensor station a few feet in front of the unit. The sensor is a photoelectric device that signals to the controller when riders are approaching the escalator or moving walk. If during the off-peak hours no persons have passed the sensor station and ridden on the unit for a certain period the controller will decide to lower the speed to 10fpm. This deceleration will be completely controlled by the variable voltage variable frequency motor speed control so that the 1.0 ft/sec2 deceleration rate will never be exceeded. The escalator or moving walk will continue operating at 10 fpm until a person approaches the unit and the sensor is activated. The controller will then accelerate the unit at 1.0 ft/sec2 so that the full operating speed of 100 fpm is achieved before the rider actually boards the escalator or moving walk. The operation of the sensors is completely interlocked so that the operating direction can never be reversed until the unit is stopped using the stop button and restarted in the opposite direction using the starting keyswitch as is done normally for all escalators and moving walks.

3) Safety Considerations

In normal operation the rider will never encounter the acceleration, deceleration or low speed operation modes. The rider will be detected by the sensor station and acceleration to full speed will be accomplished before he or she steps onto the unit. However, safety considerations must provide for the remote possibility of an equipment malfunction or some other unusual occurrence.

Numerous studies have shown that accelerations or decelerations of 1.0 ft/sec² are completely comfortable and safe for passengers on escalators, moving walks and other types of public conveyance. According to studies made by A. C. Browning accelerations of 1.93ft/sec² had virtually no affect on unsupported riders of moving walks. Also,

studies by C. F. Hirshfield showed that 99% of unsupported standees had no foot movement resulting from a acceleration of 1.0ft/sec². These test results have been previously discussed by the Escalator Committee (September 16 and 17, 1999 Minutes-Attachment 14).

Therefore, even if a rider should be accidentally be on the escalator or moving walk during acceleration/deceleration no safety hazard will occur.

Based on the above we are requesting the Escalator Committee's review and consideration for approval of TR 01-22.



National Elevator Industry, Inc. ESCALATOR.

Attachment

ASSOCIATION HEADQUARTERS

Atrium at Glenpointe • 400 Frank W. Burr Blvd. • Teaneck, New Jersey 07666-6801 • 201.928.2828 Fax: 201.928.4200

RESPOND TO:

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Salem, NY 12865-0201

518.854.9249 Fax 518.854.3257 E-mail: edonoghue@eadai.com

May 18, 2001

Mrs. Geraldine Burdeshaw American Society of Mechanical Engineers Three Park Avenue New York, NY 10016-5990

TR 01-22

Subject: Technical Revision ASME A17.1-2000, 6.1.4 and 6.2.4

Dear Geraldine:

The NEII Central Code Committee is requesting the following revisions be made to ASME A17.1-2000.

6.1.4 Rated Speed

6.1.4.1 Limits of Speed

6.1.4.1.1 The rated speed shall be not more than 0.5 m/s (100 ft/min), measured along the centerline of the steps in the direction of travel.

6.1.4.1.2 The speed attained by an escalator after start up shall not be intentionally varied. Variation of the escalator speed after start-up shall be permitted if the speed control conforms to all of the following:

(a) The acceleration and deceleration rates are limited to 0.3 m/s² (1.0 ft/s²).

(b) The rated speed is not exceeded.

(c) The minimum speed is limited to 0.05 m/s (10 ft/min).

6.2.4 Rated Speed

6.2.4.1 Limits of Speed

6.2.4.1.1 The Maximum speed of a treadway shall depend on the maximum slope at any point on the treadway. The speed shall not exceed the value determined by Table 6.2.4. 6.2.4.1.2 The speed attained by an moving walk after start up shall not be intentionally varied. Variation of the escalator speed after start-up shall be permitted if the speed control conforms to all of the following:

Mrs. Geraldine Burdeshaw American Society of Mechanical Engineers May 18, 2001 Page 2

| Attachment | : | 1 | 8 |
|------------|---|------|---|
| Page | 2 | of _ | 2 |

- (a) The acceleration and deceleration rates are limited to 0.3 m/s²(1.0 ft/s²).
- (b) The rated speed is not exceeded.
- (c) The minimum speed is limited to 0.05 m/s (10 ft/min).

Reason: Acceleration or deceleration rates of 0.3 m/s² (1.0 ft/s²) are completely safe for riders of horizontal or inclined transportation systems.

Reference: A17 Escalator and Moving Walk Committee Meeting Minutes of September 16 and 17, 1999 – Attachment 14, Page 1, Table 1. The data states that unsupported standees have virtually no equilibrium affect at accelerations of .59 m/s² (1.93 ft/s²) or less.

Very truly yours,

Edward A. Donoghue, CPCA

Code and Safety Consultant to NEII

imd

cc: NEII Members ASME A17 Committee

c:\my documents\wpdocs\2001\may\18cneii.doc

| Attachmen | t | | 14 | |
|-----------|---|----|----|--|
| Page | 1 | of | 3 | |

Machine Brake Requirements for Escalators and Moving Walks

Clarification of TR 98-30, Encompassing Rules 804.3a & 904.3a,

Maximum Average Acceleration:

Collectively, rules 804.3a & 904.3a, state that the escalator shall stop at a rate no greater than 3 ft/s². This level is suggested by A.C. Browning (1) based upon his studies done in the UK involving acceleration and deceleration of passengers on accelerating walkways. The original intent of this limit is to impose a maximum average horizontal acceleration / deceleration of no greater than .1g (3.22 ft/s²) upon passengers during an emergency stop. The intent of the limit being implied as an average can be seen in the equation used to calculate acceleration for the Browning's study;

$$(V_t - V_0) / t = a \tag{1}$$

Where V_t = Final Velocity, V_o = Original Velocity, t = time, a = acceleration

The following chart depicts Browning's analysis for avaerage accelerations of one-second duration.

Table 1

<u>Maintenance of Equilibrium Under</u>

Acceleration – Unsupported Standees

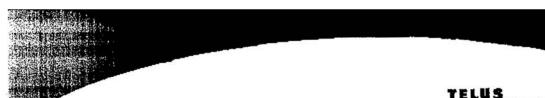
| Passenger Effects (in terms of movement) | Acceleration | G's |
|---|------------------------|------|
| Large | 4.83 fts ² | 0.15 |
| Moderate | 3.86 ft/s ² | 0.12 |
| Slight | 2.89 ft/s ² | 0:09 |
| Virtually None | 1.93 ft/s ² | 0.06 |

(1)

C.F. Hirshfeld reported similar findings in a 1932 publication titled <u>Disturbing</u> Effects of Horizontal Acceleration, from which the following chart was obtained.

Table 2
Maintenance of Equilibrium Under Acceleration

| Average Acceleration Attained | | Percent of Unsupported Standees Without Foot |
|-------------------------------|-------|---|
| Ft/s/s | G's | Movement |
| 1 | 0.031 | 99% |
| 2 | 0.063 | 95% |
| 3 | 0:094 | 87% |
| 4 | 0.125 | 67% |
| 5 | 0.156 | 42% |
| 6 | 0.188 | 12% |
| 7 | 0.219 | 4% |
| 8 | 0.250 | 1% |



convention.

May 30, 2002

To Whom It May Concern:

RE: VVVF Variable Speed Escalators

The TELUS Convention Centre has had variable speed escalators installed in our facility for the past two years. During that time we have experienced no problems with the operation of these escalators. The escalators have not raised any concerns or resulted in any injuries due to the operational characteristics.

We have received numerous positive comments from our clientele with regard to these escalators. We believe that they will reduce maintenance costs, increase escalator life and provide us with another way to showcase modern technology within our facility.

In conclusion, we feel that the "variable speed escalators" have been a positive addition to our facility. If you require further information, please contact me at (403) 261-8557.

Sincerely,

Jim Harvie

Director of Building Services

JH:lan



1992 to 2002 Celebrating Ten Years of Service

> Fujitec Canada #50, 2256-29 Street NE Calgary, AB T1Y 7G4

Phone: 735-1337 Fax: 735-1284

Email: blainea@yyc.com

May 23, 2002

To Whom It May Concern:

Re: VVVF Reduced Speed Escalators

The Calgary Airport Authority prides itself on providing the best service with the lowest landing fees for our customers. For this reason we converted our current escalators to VFD drives with reduced speed. This change has resulted in an average reduction in power consumption by 50%. With approximately forty escalators being used constantly, this change will save the Calgary Airport Authority an average of \$3000.00 per year per escalator.

Sincerely,

CALGARY AIRPORT AUTHORITY

Oct Bla

Blaine Adams

Mechanical Manager



1992 to 2002 Celebrating Ten Years of Service

Fuiltec Canada #50, 2256-29 Street NE Calgary, AB T1Y 7G4

May 23, 2002

To Whom It May Concern:

Re: VVVF Reduced Speed Escalators

The Calgary Airport Authority endorsed the use of VVVF escalators based on the following operating conditions:

1. They provide the Airport with a cost savings in both power consumption and operational time by not needed to stop and start daily.

Phone: 735-1337.

Fax: 735-1284

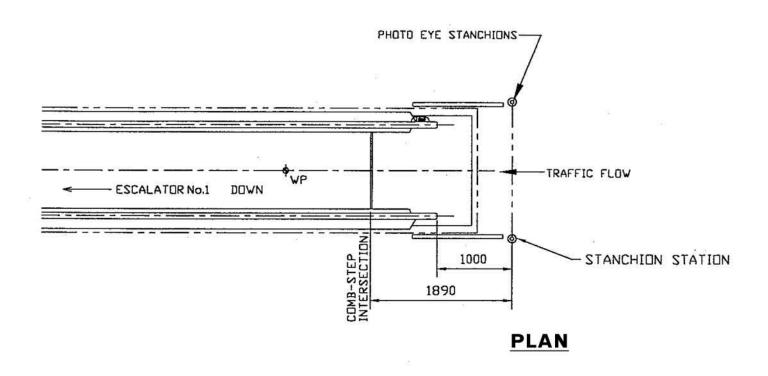
Email: blainea@yyc.com

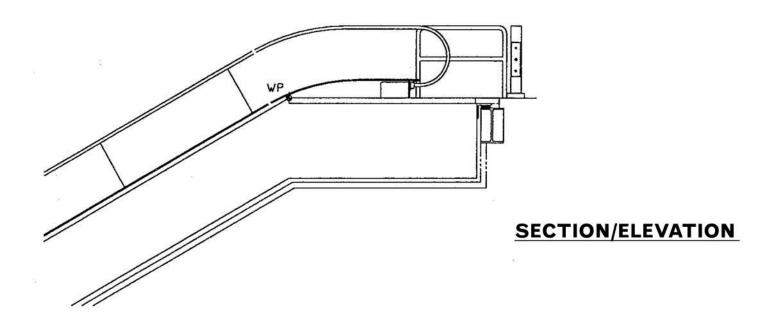
- 2. They extend the life cycle of the equipment to 30 years, thereby prolonging our capital investment, through the reduction of speed and the continual lubrication that occurs with constant movement at reduced speeds.
- 3. The equipment keeps us current with our sister airports throughout Canada, who have incorporated this as a standard.
- 4. Our customers have commended us on the use of this product and our effort to keep operating cost to a minimum.

As a public facility, we need to continually strive to adjust to our environment and customer's needs by supplying them with the best options available to prolong equipment life and reduce costs.

CALGARY AIRPORT AUTHORITY

Mechanical Manager





Appendix C

Traffic Study of WMATA Navy Yard Escalators

Appendix C

National Institute of Building Sciences Traffic Study

Submitted to:

Nanne Davis Eliot, Project Manager

Submitted by:

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Intermittent Escalator Committee:

National Institute of Building Sciences (NIBS)

Washington Metropolitan Area Transit Authority (WMATA)

National Elevator Industry, Inc. (NEII)

KONE, Inc.

Otis Elevator Company

FujitecAmerica, Inc.

Schindler Group

ThyssenKrupp Elevator

Bayline Lift Technologies

American Public Transportation Association (APTA)

Federal Transit Administration (FTA)

U.S. General Services Administration (GSA)

American Society of Mechanical Engineers (ASME)

The Intermittent Escalator Committee would especially like to thank these two gentlemen for their assistance and contribution to the success of the traffic study:

Gedion Gebremariam, WMATA Elevator/Escalator Master Technician **Izaak Spriggs**, WMATA Elevator/Escalator Journeyman Technician

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1.0 EXECUTIVE SUMMARY

The National Institute of Building Sciences (NIBS) is a non-profit, non-governmental organization that brings together representatives of government, industry, professionals, labor, and consumers. The NIBS focuses on the identification and resolution of problems and potential problems that hamper the construction of safe, affordable structures for housing, commerce, and industry throughout the United States.

RSMeans, a leading construction cost information leader providing business solutions and third party validation to manufacturers, was commissioned to conduct a study to analyze traffic patterns on escalators. The results will enable manufacturers to develop energy savings and initial cost and life expectancy data useful in life cycle cost analyses for Intermittent Escalators (IE).

Definition of Intermittent Escalators. The Energy Act defines the term "intermittent escalator" as an escalator that remains in a stationary position until it automatically operates at the approach of a passenger, returning to a stationary position after the passenger completes travel. (ASME A17.1, a public safety code, permits neither automatic on/off nor variable speed as related to escalators.) Based on the use of Intermittent Escalators in Europe and Asia, it is not recommended that the escalator come to a complete stop, but that speed be reduced to 20' per minute (6 meters per minute) for standby or sleep mode.

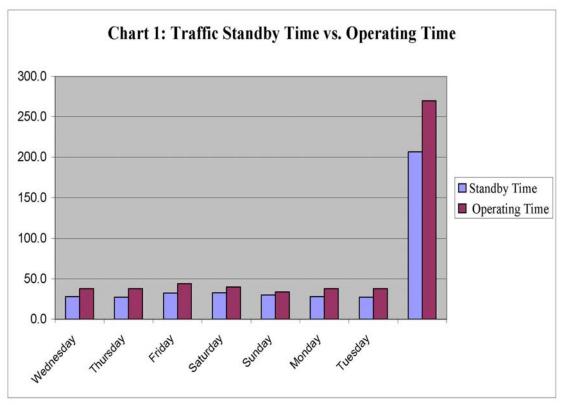
The research objective was to evaluate the current technology available for detecting, counting, and reporting traffic patterns, specifically standby and operating times associated with escalators in the Washington Metropolitan Area Transit Authority (WMATA) system. The study was limited to observing two escalators currently in use.

It was anticipated that the study would quantify and validate the standby and operating times during a one-week observation, using electrical counters to collect data for analysis. The project Scope is summarized in Table 1 as follows:

Table 1: Project Scope - Operating Data Combined Data for Up and Down Escalator One-Week Observation

| | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
|---------------------|----------|----------|-----------|----------|---------|----------|----------|
| Start Time | 5:00 AM | 5:00 AM | 5:00 AM | 5:00 AM | 5:00 AM | 7:00 AM | 7:00 AM |
| Finish Time | 12:00 AM | 12:00 AM | 12:00 AM | 12:00 AM | 3:00 AM | 3:00 AM | 12:00 AM |
| Standby | 28.2 | 27.5 | 27.9 | 27.5 | 32.4 | 32.9 | 30.2 |
| Time (hours) | | | | | | | |
| Total Actual | 38.0 | 38.0 | 38.0 | 38.0 | 44.0 | 40.0 | 34.0 |
| Operating | | | | | | | |
| Time (hours) | | | | | | | |

Between May 15 and May 23, 2006, a Traffic Study was conducted at Navy Yard Metro Station in Washington, DC. Representatives from RSMeans, NIBS, and WMATA were present. Set-up and functionality were established on May 15 and May 16, 2006. Data collection proceeded May 17 to May 23.



As illustrated in Chart 1, the results of this study were that the total standby time was 77 percent of the total operating time on average. The standby time for the Up escalator was 82 percent while for the Down escalator it was 71 percent. There is no correlation between the two. Moreover, due to the unique condition of each Metro station, every escalator application is different. There are neither traffic pattern studies nor benchmark information available. Professional users are therefore encouraged to exercise judgment according to location and escalator specifications.

It is important to note that the Navy Yard Metro Station is not a major hub. The percentage of standby time at L'Enfant Plaza, Gallery Place, and Metro Center may even show reversed results. RSMeans recommends developing a strategic plan to fund research on the technology and management of the Intermittent Escalator (IE) program in order to realize energy savings by taking advantage of off-peak (sleep mode) traffic times.

The following report contains details of the metrics observed in the Traffic Study. (*See Appendix Figure 1: Traffic Standby Time vs. Operating Time Comparison and Figure 3: Work Measurement*) In addition, significant overall findings are discussed and analyzed, and

recommendations made relevant to the design and fine-tuning of the model for future traffic pattern studies.

2.0 METHODOLOGY

RSMeans, a leading provider of construction cost information, was hired to conduct the study of escalator traffic. Washington Metropolitan Area Transit Authority (WMATA) volunteered to set up the study counter and data collection mechanisms. Neither WMATA nor RSMeans has any vested interest in the results of the study. Every effort was made to insure it was fair and impartial.

There are two major procedural aspects required to accomplish this traffic study:

- (1) Technical research to find the most economical equipment available to detect, count, record, and report the results, and
- (2) Preparation of site to facilitate data collection.

2.1 Technical Research:

Research was conducted to identify people counter technologies and methodologies in use across the U.S. Internet research and interviews with sales representatives and IT technical support indicated different levels of technology available for traffic data collection. These are discussed below.

Sensors:

- Sensor Feature: Detection either non-directional (counts up regardless of traffic) or directional (counts incoming and outgoing traffic separately). Since escalators move in only one direction at a time, either up or down, the non-directional sensor was selected for the project.
- Sensor Installation Method: Either vertical or horizontal
- Sensing Distance (Range): A minimum of 6 feet up to a maximum of 45 feet (1.8 to 13.7 meters)
- Types: Photoelectric proximity sensor, acoustic proximity sensor, radiofrequency (RF) proximity sensor, photo eye sensor, infrared (IR) beam interruption sensor, and thermal imaging camera

On the basis of the research, RSMeans elected to use the photo eye sensor to detect passenger traffic on the escalators.

Collecting, Recording, and Reporting Technology:

- User-friendly software is designed to collect and report data; some sophisticated administrative tools integrate and automate the collection and reporting of traffic data from wireless or wire counters in different locations.
- PLC (Programmable Logic Controller) monitors and records data.

• For the reporting feature, in the U.S. people-counter reporters are currently based on counts per half hour. In order to report counts per minute, the existing programs would have to have been rewritten.

Due to the limitations of recording and reporting technology available, Mr. Tom Nurnburg of KONE, Inc. proposed the standby timing circuit for a usage measuring device that could be turned on and off manually at the same time as the escalator is turned on or off. Two units were assembled accordingly, giving RSMeans and WMATA a chance to observe and assess before setting up on May 15, 2006. (See Figure 3: Schematic Diagram of Standby Timing Circuit)

2.2 Work Activity Set-Up

The Standby Timing Circuit electronics equipment was used for collecting and recording escalator usage and operated as described below:

- When a rider triggers the photo eye it opens the contact and cuts the power to the delay timer. After the rider passes, the photo eye signal is remade and the photo eye contact closes.
- The photo eye contact closure starts the delay "on" timer process which is set/adjusted to the escalator rise and speed value for standby operation (1–2 minutes).
- If another rider triggers the photo eye before the delay timer times out, the delay timer relay is reset to the initial time by opening the photo eye contact, and the timing process is restarted.
- If another rider does not trigger the photo eye, the delay timer contact closes and relays power to the standby time hour meter and standby counter, raising it by 1.
- The circuit remains in this state, and the standby hour meter continues to record/accumulate time until the photo eye is triggered by another rider.
- The trigger of the photo eye by another rider opens the photo eye contact, removes power from the delay timer, causing a reset, and the process is repeated.
- The operating time meter runs continuously with the escalator so that the percent (%) of time at standby can be determined.
- The standby hour meter accumulates time when the escalator could be in slow-down mode.
- The counter also counts the number of standby time occurrences.

A photo eye and reflector were installed on the newel end at the upper level of each of the two escalators. The sensing distance of the photo eye was 13 feet (4 meters). The standby timing circuit box was embedded inside the chain system housing. (See Photos 1, 2, &3 of Reflector, Photo Eye, Standby & Operating Timer and Delay Time Adjusted) The elapsed time for a rider to be on and off the escalator was 24 seconds. However, KONE, Inc. suggested adjusting the delay timer to 45 seconds for safety reasons, applying a multiplier factor of between 1.5 and 2. The RSMeans representative validated and recapitulated the traffic pattern data. Tasks correlate to those listed in the activities time

charts. (See Figure 2: Work Measurement (WM2.1 and WM2.2). For recapitulated results, see Figure 1: Traffic Standby Time vs. Operating Time Comparison.)

3.0 DATA COLLECTION & APPROACH

The following is a description of key steps involved in defining the objectives and collecting data for the Traffic Study:

Step 1: Research/Study Control Guide. An RSMeans professional engineer reviewed the installation and data collection requirements to assess and define the Standby Time versus Operating Time metrics to be evaluated. A Study Control Guide was developed which identified the two discrete process times to be measured. Traffic was observed on two parallel escalators, one Up and one Down, from opening to closing, during 7 days of a week. The objective was to measure the accumulated time when the interval between passengers exceeded the elapsed time for a rider.

Step 2: Data Collection. As detailed in the Study Control Guide (*See Figure 2: Work Measurement*), the observer recorded time and reported work measurement data at 0.10 hour intervals.

Between May 17 and May 23, 2006, this traffic study was conducted in the Navy Yard Metro station in Washington, DC. The WMATA crew turned the switch of the Escalator Standby Timing Circuit electronics equipment on and off based on the Metro schedule. (*See Table 1: Project Scope*)

Observers recorded the start and finish times on each application (Up and Down escalator) at 0.10 hour intervals at the beginning of the day, for the seven day period, according to the Metro schedule. At the end of data collection, standby time was calculated by subtracting the start time from the finish time read from gauge #2 and based on the operating time according to the Metro schedule.

Specifications for the escalator were provided by WMATA, which include rise, step width, number of flat steps, voltage supply, size of motor HP (kW), balustrade type (high deck/stainless steel), and whether the escalator is capable of being used at variable speeds, i.e., intermittently.

Step 3: Recapitulated Work Measurement. Data was compiled on two applications as follows:

1. Up Escalator:

The project started at 5:00 AM on May 17, 2006, and concluded at 12:00 AM, on May 23, 2006. The total actual operating time was 135 hours while the total standby time was 110.7 hours, for the 7-day observation time period. (*The results*

are recapitulated in Figure 2: Work Measurement (WM2.1) and Figure 4: Recapitulated Work Measurement for an Up Escalator.)

2. Down Escalator:

Using identical start and finish times, the total actual operating time was 135 hours and the total standby time was 95.5 hours, for the 7-day observation time period, on the Down escalator. (*The results are recapitulated in Figure 2: Work Measurement (WM2.1) and Figure 4: Recapitulated Work Measurement for a Down Escalator.*)

Step 4: Traffic Standby Time Analysis. Actual standby time and operating time data on the two escalators were recorded and combined, with the addition of a percent (%) column. (*See Figure 5: Escalator Traffic Standby Time vs. Operating Time Percentage Comparison*)

4.0 KEY FINDINGS

The data showed that the total standby time was 77 percent of the operating time. The actual standby time for the Up escalator was 82%, and for the Down escalator it was 71%. There is no correlation between the two. Moreover, due to the unique condition of each Metro station, every escalator will be different.

RSMeans observed that because Navy Yard is not a major hub, the percentage of standby time compared to operating time is higher than it would be for L'Enfant Plaza, Gallery Place, or Metro Center. This points to the need to collect data on escalators with heavy traffic before extrapolating the results.

5.0 CONCLUSIONS & RECOMMENDATIONS

This pilot traffic study indicates the need for a strategic plan to fund research on the technology and management of Intermittent Escalators (IE), wherever there is a high percent of standby time.

Additional recommendations for future traffic studies:

- Seek a variance of the safety code, ASME A17.1, to accommodate an actual study of intermittent escalator application. The code currently permits neither automatic on/off nor variable speed as related to escalators.
- Be flexible when installing the detection system and counter in order to adapt to wireless or hard-wire constraints.
- Visual/manual counting time between passengers on the escalator is a laborintensive process. It is recommended observers utilize technology to detect, count, and report data, supported by an escalator mechanic and IT specialist.

Because there is a lack of traffic pattern studies and benchmark information currently available, professional users are encouraged to exercise judgment according to job and escalator specifications.

Figure 1: Traffic Standby Time vs. Operating Time Comparison

Combined Up and Down Escalator Times

| Application/Date | 5/17 | 5/18 | 5/19 | 5/20 | 5/21 | 5/22 | 5/23 | Accumulated Time |
|-----------------------|-----------|----------|--------|----------|--------|--------|---------|------------------|
| | Wednesday | Thursday | Friday | Saturday | Sunday | Monday | Tuesday | |
| Standby Time | 27.9 | 27.5 | 32.4 | 32.9 | 30.2 | 28.2 | 27.5 | 206.6 |
| Operating Time | 38.0 | 38.0 | 44.0 | 40.0 | 34.0 | 38.0 | 38.0 | 270.0 |

Figure 2: Work Measurement

Application: Traffic Pattern Study

Cocation: Washington Metropolitan Area Transit Authority (Navy Yard)
Observer: WMATADS Means

| Date | Work Activity | UP Escalator # F05W04 | Start Time | Finish Time | Actual Time |
|-----------|-------------------------------------|-----------------------------------|------------|-------------|-------------|
| 5/16/2006 | Operating Time (Gauge #1) | Testing Gauge #1 and Gauge #2. | 5:00 AM | 12:00 PM | 19 hours |
| Tuesday | Note: one-hour interval | Gauge #1, reading starts 1.6 hour | 1.6 | 21.3 | 19.7 |
| | Standby Accumulated Time (Gauge #2) | Gauge #2, reading starts 0.9 hour | 0.9 | 16.1 | 15.2 |
| 5/17/2006 | Operating Time (Gauge #1) | | 5:00 AM | 12:00 AM | 19 hours |
| | | | 21.3 | 40.8 | 19.5 |
| | Standby Accumulated Time (Gauge #2) | | 16.1 | 31.2 | 15.1 |
| 5/18/2006 | Operating Time (Gauge #1) | | 5:00 AM | 12:00 AM | 19 hours |
| | | | 40.8 | 60.1 | 19.3 |
| | Standby Accumulated Time (Gauge #2) | | 31.2 | 46.3 | 15.1 |
| 5/19/2006 | Operating Time (Gauge #1) | | 5:00 AM | 3:00 AM | 22 hours |
| | | | 60.1 | 82.1 | 22.0 |
| | Standby Accumulated Time (Gauge #2) | | 46.3 | 63.9 | 17.6 |
| 5/20/2006 | Operating Time (Gauge #1) | | 7:00 AM | 3:00 AM | 20 hours |
| | | | 82.1 | 102.4 | 21.3 |
| | Standby Accumulated Time (Gauge #2) | | 63.9 | 81.1 | 17.2 |
| 5/21/2006 | Operating Time (Gauge #1) | | 7:00 AM | 12:00 AM | 17 hours |
| | | | 102.4 | 120.1 | 17.7 |
| | Standby Accumulated Time (Gauge #2) | | 81.1 | 96.6 | 15.5 |
| 5/22/2006 | Operating Time (Gauge #1) | | 5:00 AM | 12:00 AM | 19 hours |
| | | | 120.1 | 139.3 | 19.2 |
| | Standby Accumulated Time (Gauge #2) | | 96.6 | 111.9 | 15.3 |
| 5/23/2006 | Operating Time (Gauge #1) | | 5:00 AM | 12:00 AM | 19 hours |
| | | | 139.3 | 158.8 | 19.5 |
| | Standby Accumulated Time (Gauge #2) | | 111.9 | 126.8 | 14.9 |

WM2.1 - Traffic Pattern Study Up Escalator

Application: Traffic Pattern Study

Location: Washington Metropolitan Area Transit Authority (Navy Yard) Observer: WMATA/RS Means

| Date | Work Activity | Down Escalator # F05W05 | Start Time | Finish Time | Actual Time |
|-----------|------------------------------------|-----------------------------------|------------|-------------|-------------|
| 5/16/2006 | Operating Time (Gauge # | Testing Gauge #1 and Guage #2. | 5:00 AM | 12:00 PM | 19 hours |
| Tuesday | Note: one-hour interval | Gauge #1, reading starts 2.2 hour | 2.2 | 21.9 | 19.7 |
| | Standby Accumulated Time (Gauge #2 | Gauge #2, reading starts 1.2 hour | 1.2 | 14.6 | 13.4 |
| 5/17/2006 | Operating Time (Gauge # | | 5:00 AM | 12:00 AM | 19 hours |
| | E | | 21.9 | 41.4 | 19.5 |
| | Standby Accumulated Time (Gauge #2 | | 14.6 | 27.4 | 12.8 |
| 5/18/2006 | Operating Time (Gauge # | | 5:00 AM | 12:00 AM | 19 hours |
| | | | 41.4 | 60.7 | 19.3 |
| | Standby Accumulated Time (Gauge #2 | | 27.4 | 39.8 | 12.4 |
| 5/19/2006 | Operating Time (Gauge # | | 5:00 AM | 3:00 AM | 22 hours |
| | | | 60.7 | 82.8 | 22.1 |
| | Standby Accumulated Time (Gauge #2 | | 39.8 | 54.6 | 14.8 |
| 5/20/2006 | Operating Time (Gauge # | | 7:00 AM | 3:00 AM | 20 hours |
| | | | 82.8 | 103.0 | 20.2 |
| | Standby Accumulated Time (Gauge #2 |) | 54.6 | 70.3 | 15.7 |
| 5/21/2006 | Operating Time (Gauge # | | 7:00 AM | 12:00 AM | 17 hours |
| | | | 103.0 | 120.7 | 17.7 |
| | Standby Accumulated Time (Gauge #2 |) | 70.3 | 85.0 | 14.7 |
| 5/22/2006 | Operating Time (Gauge # | | 5:00 AM | 12:00 AM | 19 hours |
| | / | | 120.7 | 140.0 | 19.3 |
| | Standby Accumulated Time (Gauge #2 | | 85.0 | 97.9 | 12.9 |
| 5/23/2006 | Operating Time (Gauge # | | 5:00 AM | 12:00 AM | 19 hours |
| | | | 140.0 | 159.4 | 19.4 |
| | Standby Accumulated Time (Gauge #2 | | 97.9 | 110.5 | 12.6 |
| | | | | | |

WM2.2 - Traffic Pattern Study Down Escalator

Figure 3: Schematic Diagram of Standby Timing Circuit

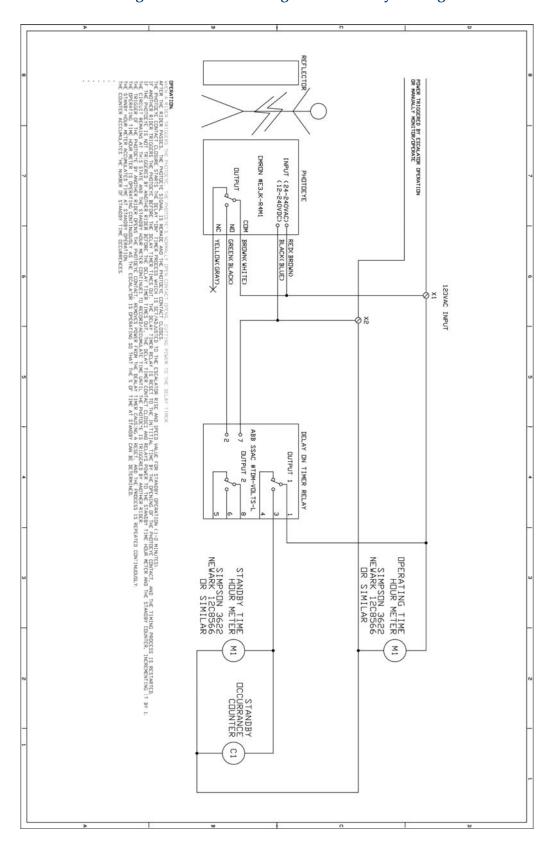


Figure 4: Recapitulated Work Measurement

Up Escalator

| Application/Date | 5/17 | 5/18 | 5/19 | 5/20 | 5/21 | 5/22 | 5/23 | Accumulated Time |
|-----------------------|-----------|----------|--------|----------|--------|--------|---------|-------------------------|
| | Wednesday | Thursday | Friday | Saturday | Sunday | Monday | Tuesday | |
| Standby Time | 15.1 | 15.1 | 17.6 | 17.2 | 15.5 | 15.3 | 14.9 | 110.7 |
| Operating Time | 19.0 | 19.0 | 22.0 | 20.0 | 17.0 | 19.0 | 19.0 | 135.0 |

Down Escalator

| Application/Date | 5/17 | 5/18 | 5/19 | 5/20 | 5/21 | 5/22 | 5/23 | Accumulated Time |
|-----------------------|-----------|----------|--------|----------|--------|--------|---------|-------------------------|
| | Wednesday | Thursday | Friday | Saturday | Sunday | Monday | Tuesday | 3 |
| Standby Time | 12.8 | 12.4 | 14.8 | 15.7 | 14.7 | 12.9 | 12.6 | 95.9 |
| Operating Time | 19.0 | 19.0 | 22.0 | 20.0 | 17.0 | 19.0 | 19.0 | 135.0 |

R4.1 - Traffic Pattern Study Up Escalator

R4.2 - Traffic Pattern Study Down Escalator

Figure 5: Traffic Standby Time vs. Operating Time Percentage Comparison

| Application | Accumulated Time | Percentage Standby Time vs. |
|-----------------------|------------------|-----------------------------|
| | | Operating Time |
| Standby Time | 206.6 | 77% |
| Operating Time | 270.0 | 100% |

Note: Using Operating time as benchmark (denominator)

Chart 5: Escalator Traffic Standby Time vs. Operating Time Percentage Comparisons

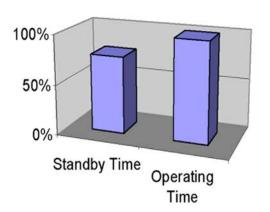


Photo 1: Reflector



Photo 2: Photo Eye



Photo 3: Standby & Operating Timer and Delay Time Adjuster



Photo 4: Escalator



Appendix D

Life Cycle Cost Calculations

Appendix D

BUILDING LIFE-CYCLE COST ANALYSIS
Life Cycle Cost Comparison of New Escalator with Standard Operation vs. Intermittent/Slow Down Operation updated: 1 April 2006

INTERMITTENT/SLOW DOWN ESCALATOR STUDY

User input fields are indicated in blue.

IMPORTANT NOTE: This spreadsheet should be updated (replaced) every April, after DOE releases updated energy price escalation factors.

| Source: U.S. Bureau of the Census | (Region 3) | WEST MIDWEST (Region 2) | | Uniform Electric Price Escalation Rate(to use DOE escalation Rate | | (0=Noffe, 1=N.Gas; z=LFG, 3=Dist Off, 4=Resid Off, 3=Coar) | Second Fuel Type 0 (None) | | | Analysis Sector 2 (Commercial) | (1 dilough +, see hab below, s-o.s. average) | DOE Fuel Price Escalation Region 3 (South) | ı | | Number of Analysis Years 25 | | Real Discount Rate for this Analysis 3.0% | | Year Project comes "On-I ine" 2006 | | DOE/FEMIL FISCAL YEAR 7000 | | Basic Data, this analysis | | Visit http://www.doe2.com to download the current conv |
|-----------------------------------|------------|-------------------------|------|---|------|--|---------------------------|-------|--------------------|--------------------------------|--|--|----------|----------|-----------------------------|---|---|---------|------------------------------------|------------|----------------------------|----------|---------------------------------|------------|--|
| | | NORTHEAST (Region 1) | | (to use DOE escalation rates, which vary by year, leave this entry empty) (to use DOE escalation rates, which vary by year, leave this entry empty) | | | | | Real-to-Nominal: | | | Nominal-to-Real: | Convert: | | 200 | * "nominal" assumes 1.75% effective ger | 30-year | 10-year | 7-year | OND 3-year | | | FY 2006 Federal Discount Rates: | | |
| | | | • | by year, by year, | | | 4.6% | 1.60% | 3.0% | 3 | 3.0% | 4.6% 1.60% | | | | s 1.75% ¢ | | | 2.0% | | 3.0% 3.5% | real | scount F | | |
| | , | | • | leave this entry empty) leave this entry empty) | | | Nominal Discount Rate | | Real Discount Rate | | Real Discount Rate | Nominal Discount Rate | | | 90.00 | effective general inflation | 4.6% | 4.4% | 4.3% | 4.1% | 4.6% | nominal* | Rates: | | |
| | | | 25 | 23 24 | 22 | 21 | 39 | 18 | 17 | 16 | 15 | 13 | 12 | <u> </u> | 10 | 9 (| ∞ - | 7 | ກ ເ | 4 ת | ى د |) N |) <u> </u> | Year# | |
| | | | 100% | 100% 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | Multiplier | |

| | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 28 | 17 | 16 | 15 | 4 | 3 | 12 | ⇉ | 10 | 9 | œ | 7 | 6 | Ŋ | 4 | ω | 2 | _ | 0 | # | Year | | | | |
|---------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------------|---|--------------------------|----------------------------|---|
| • | | | | | | | | | | | | | | | | | | | | | | | | | | First Cost | of Cost | r Description | (e.g., 1st c | Inves | | Escalator v With VSD |
| \$5,550 | \$ 0 | \$5,550 | Constant \$ | | (e.g., 1st cost, replacement, residual, | nvestment-Related Costs | NON- | Escalator with Slow Down Operation With VSD |
| \$5,550 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$5,550 | PV\$ | Discounted | nt, residual) | Costs | NNUAL REC | own Opera |
| | | | | | | | | | | | | | | | | | | | | | | | | | | n/a | of Cost | Description | (e.g., non | Operat | NON-ANNUAL RECURRING COSTS | ition |
| \$0 | \$0 | \$0 | \$0 | \$ 0 | \$0 | \$ 0 | \$ 0 | \$0 | \$ 0 | \$0 | \$ 0 | \$ 0 | \$ 0 | \$0 | \$ 0 | n/a | Constant \$ | | (e.g., non-annual maintenance) | Operations-Related Costs | STS | Analysis Yrs befon |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | n/a | PV\$ | Discounted | enance) | Costs | | Analysis Month/Year:4/2006 Yrs before "On-Line":0 |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | Constant \$ | Electric | Recurring | Annual | <u>m</u> |) |
| | 0.72% | 1.10% | 0.09% | 0.09% | 0.41% | 0.55% | 0.89% | 0.61% | 0.09% | 0.47% | 0.57% | 0.14% | 0.77% | 0.48% | 0.10% | -0.10% | -0.67% | -0.14% | 0.48% | -1.14% | -1.77% | -1.24% | -1.76% | -3.36% | -2.92% | | % | Escalation | Differential | Electric | ELECTRIC COSTS | Years of Years in |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | | PV\$ | w/Fuel Esc. | Electric | Discounted | STS | Years of Project Service: 25 Years in Analysis Period 25 |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | Constant \$ | | Recurring | Annual | Z O | h:25 d25 |
| | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | | % | Escalation | Differential | | NO 2ND FUEL USED | FEMF |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | | PV\$ | w/Fuel Esc. | | Discounted | SED | FEMP Fiscal Year: 2006 Disc. Rate: 3.0% |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$ 0 | Constant \$ | (e.g., ma | Recurring | Annual | RECURRI | 2006 3.0% |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | | PV\$ | (e.g., maintenance) | Recurring | Discounted | ANNUAL RECURRING COSTS | DOE I Analysis |
| | 2030 | 2029 | 2028 | 2027 | 2026 | 2025 | 2024 | 2023 | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | | Date | Year | | | 101 | DOE Region: South alysis Sector: Comn |
| \$5,550 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$5,550 | PV\$ | Costs | Total | Discounted | TOTAL COSTS | DOE Region: South Analysis Sector: Commercial |
| \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | PV\$ | Costs | Cumulative | Discounted | COSTS | |
| n/a | \$39,004 | \$37,751 | \$36,466 | \$35,152 | \$33,799 | \$32,407 | \$30,976 | \$29,508 | \$28,004 | \$26,462 | \$24,874 | \$23,243 | \$21,569 | \$19,846 | \$18,081 | \$16,268 | \$14,402 | \$12,478 | \$10,489 | \$8,438 | \$6,332 | \$4,146 | \$1,870 | (\$494) | (\$2,956) | (\$5,550) | PV \$ | Savings | Cumulative | Discounted | CUMULATIVE SAVINGS | |
| 2.2 | | | | | | | | | | | | | | | | | | | | | | | 2.2 | | | | yrs | Payback | Discounted | | Payback | |

Note:

The costs shown on this spreadsheet are the additional costs incurred by Standard Operation, vs. Slow Down Mode.

Note:

They are comporised of \$1800 additional energy costs and \$924 additional maintenance costs.

It is assumed that intermittent/slow down operation will save 2% of the annual \$46,200 maintenance cost or \$924

Life-Cycle Costs Summary (Incremental 1st Costs Only, No Residual Costs) Intermittent/Slow Down Escalator Savings Analysis

Life Cycle Cost Comparison of New Escalator with Standard Operation vs. Intermittent/Slow Down Operation

Saving

Adjusted

| | peration With VSD ** LCC Ch ** Simple I | | * alternat | Base No Va | | Case | | |
|---|--|--|--|------------------------------|------------------|--------------|--|----------|
| Analysis Assumptions: | With VSD * LCC Choice ** Simple Payback choice | | * alternative with least life-cycle cost * alternative with most rapid simple payback | Base No Variable Speed Drive | | Description | | |
| | (\$5,550) | | yback | \$0 | | & | One-Time Costs | |
| # of Ye | (\$5,550) \$1,800 | | 90,000 | \$0 | | PV\$ | | |
| Real D ars before P DOE | \$1,800 | | é | \$1,800 | | \$ | 1st vear | |
| DOE/FEMP Fiscal Year Real Discount Rate for this Analysis Number of Analysis Years # of Years before Project Occupancy or Opration DOE Fuel Price Escalation Region Analysis Sector | \$40,895 | Life-Cycle S. | 6 | \$40,895 | | PV\$ | Total Utility | |
| DOE/FEMP Fiscal Year nt Rate for this Analysis umber of Analysis Years Occupancy or Opration Price Escalation Region Analysis Sector | \$28,465 | AVINGS | é | \$28,465 | | PV \$ | - 00 | |
| 2006 3.0% 5 25 0 0 | \$924 | (negative | é | \$924 | Life-Cyc | 6 | Maii 1st vear | |
| (South) (Commercial) | \$16,090 | entries in | é | \$924 \$16,090 | Life-Cycle COSTS | | Maintenance | |
| | \$58,445 \$39,004 \$39,004 3.1 including 1st yr maintenance cost savings: 2.04 | Life-Cycle SAVINGS (negative entries indicate increased costs) | 90,000 | \$63,995 | | PV \$ | Total Undisc I CC | |
| | \$39,004 \$39,004 naintenance cost savings | sed costs) | 90,000 | \$44,554 | | PV \$ | Total | |
| | \$39,004 ost savings: | | TV a | n/a | ı | | Net Savings | |
| | 3.1 2.04 | | l V d | n/a | | yrs | Simple Pavhack I | |
| | 2.21 | | W a | n/a | | yrs | Discnt'd I | |
| | \$5,550 | | \$3,550 | \$0 | | PV \$ | Simple Discnt'd Investment Payhack Payhack Related | |
| | \$44,554 | | é | \$44,554 | | PV\$ | Operations Related | |
| | 8.03 | | lVa | n/a | | SIR | Invest | ţ |
| | 11.95% | | II/d | n/a | | AIRR | Rate-of- | Internal |

The Simple Payback period in years using the BLCC5 program is 3.1 years. If the maintenance savings are included in the calculation the payback period is 2.04 years. Simple payback is defined as the Investment Cost divided by First Year Savings. The BLCC5 program does not recognize maintenance savings in this calculation.

BUILDING LIFE-CYCLE COST ANALYSIS Life Cycle Cost Comparison of Existing 10 Year Old Escalator with Retrofitted Intermittent/Slow Down Escalator updated: 1 April 2006

Intermittent/Slow Down Retrofit Escalator Study

User input fields are indicated in blue.

IMPORTANT NOTE: This spreadsheet should be updated (replaced) every April, after DOE releases updated energy price escalation factors.

| Source: U.S. Bureau of the Census | | WEST MIDWEST (Region 2) | | Uniform Electric Price Escalation Rate (to | | | Second Fuel Type 0 (A | (1-1 Notworkia), 6-Norminologi, 9-maasilal) | (1=Residential: 2=Commercial: 3=Industrial) |) | | DOE Fuel Price Escalation Region 3 (S | Number of Project Service Years 25 | | | Real Discount Rate for this Analysis 3.0% | | | Year Analysis Performed 2006 | | DOE/FEMP Fiscal Year 2006 | Dasic Data, tills altalysis | Rasio Data this analysis | Visit http://www.doe2.com to download the current copy. | MEOR IAM I NOTE: This spreadsheet should be updated (replaced) every Apin, after DOE releases updated energy price escalation radions. |
|-----------------------------------|------------------|-------------------------|------|--|------|----------|-----------------------|---|---|----------------------|------|---------------------------------------|------------------------------------|------|---|---|------|------|------------------------------|------|---------------------------|-----------------------------|--------------------------|---|--|
| e Census | South (Region a) | NORTHEAST (Region 1) | | (to use DOE escalation rates, which vary by year, leave this entry empty) (to use DOE escalation rates, which vary by year, leave this entry empty) | | | (None) | 10-10-10-10-10-10-10-10-10-10-10-10-10-1 | (Commercial) Real-to-Nominal: | - | | (South) Convert. Nominal-to-Real: | Convert. | | * "nominal" e | (4) | _ | | | OMB | DOE | 1 1 2000 1 60 | EV 2006 Ea | ad the current copy. | , aller DOE releases updated energy p |
| | | | | ich vary by ye ich vary by ye | | | 4.6% | | minal: 30% | 3.0% | | -Real: 4.6% | | | assumes 1.75 | 30-year 3.0% | | | | | DOE/FEMP 3.0% | real nomi | deral Discour | | once escalation i |
| | | | , | ar, leave this entry empty) ar, leave this entry empty) | | | | | Real Discount Rate | % Real Discount Rate | | % Nominal Discount Rate | | | * "nominal" assumes 1.75% effective general inflation | % 4.6% | | | | | | nominal* | t Pates: | | actors. |
| | | | 25 | 23 24 | 22 | 20 21 | 19 | 18 | 16 17 | 15 | 14 | 13 1 | 1 1 1 1 | 10 | 9 | 8 | 7 | 6 | 51 | 4 | ωι | 2 - | Year# | ζ. | |
| | | | 100% | 100% 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | Multiplier | Occ/Use | : |

(0=None,

| | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | ⇉ | 10 | 9 | œ | 7 | 6 | σı | 4 | ω | 2 | _ | 0 | # | Year | | | | |
|----------|----------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------|-------------|-------------|---------------------|---|--------------------------|----------------------------|--|
| | | | | | | | | | | | | | | | | | | | | | | | | | | First Cost | of Cost | D | (e.g., 1st cc | Invest | | Escalator - Standard Operation - Retrofit No Variable Speed Drive |
| \$0 | \$0 | \$ 0 | \$0 | \$ 0 | Constant \$ | | (e.g., 1st cost, replacement, residual) | nvestment-Related Costs | NON-A | Standard C |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | PV\$ | ۵ | nt, residual) | Costs | NNUAL REC | peration - ve |
| | | | | | | | | | | | | | | | | | | | | | | | | | | n/a | of Cost C | Description | (e.g., non-e | Operation | NON-ANNUAL RECURRING COSTS | Retrofit |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$ 0 | \$ 0 | \$0 | \$0 | \$ 0 | \$ 0 | \$ 0 | \$ 0 | \$0 | \$0 | \$0 | \$ 0 | \$0 | \$0 | \$ 0 | \$ 0 | \$ 0 | \$ 0 | \$0 | \$0 | n/a | Constant \$ | _ | (e.g., non-annual maintenance) | Operations-Related Costs | SI | Analysis N Yrs before |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | n/a | PV\$ | Discounted | | osts | | Analysis Month/Year:4/2006 Yrs before "On-Line":0 |
| \$27,000 | | | | | | | | | | | \$1,800 | \$1,800 | \$1,800 | \$1,800 | \$1,800 | \$1,800 | \$1,800 | \$1,800 | \$1,800 | \$1,800 | \$1,800 | \$1,800 | \$1,800 | \$1,800 | \$1,800 | \$1,800 | Constant \$ | | g | Annual | ₽ | 2006 |
| | 0.72% | 1.10% | 0.09% | 0.09% | 0.41% | 0.55% | 0.89% | 0.61% | 0.09% | 0.47% | 0.57% | 0.14% | 0.77% | 0.48% | 0.10% | -0.10% | -0.67% | -0.14% | 0.48% | -1.14% | -1.77% | -1.24% | -1.76% | -3.36% | -2.92% | | % | Escalation | Differential | Electric | ELECTRIC COSTS | Years of F Years in A |
| \$19,393 | | | | | | | | | | | \$1,038 | \$1,063 | \$1,093 | \$1,117 | \$1,145 | \$1,179 | \$1,215 | \$1,260 | \$1,300 | \$1,332 | \$1,388 | \$1,456 | \$1,518 | \$1,592 | \$1,696 | | PV \$ | w/Fuel Esc. | Electric | Discounted | S | Years of Project Service: 25 Years in Analysis Period 25 |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | Constant \$ | | Recurring | Annual | NO NO | :25 125 |
| | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | | % | Escalation | Differential | | NO 2ND FUEL USED | FEME |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | | PV\$ | w/Fuel Esc. | | Discounted | SED | FEMP Fiscal Year: 2006 Disc. Rate: 3.0% |
| \$13,860 | | | | | | | | | | | \$924 | \$924 | \$924 | \$924 | \$924 | \$924 | \$924 | \$924 | \$924 | \$924 | \$924 | \$924 | \$924 | \$924 | \$924 | \$924 | Constant \$ | (e.g., ma | Recurring | Annual | RECURRI | 2006 3.0% |
| \$11,031 | | | | | | | | | | | \$593 | \$611 | \$629 | \$648 | \$668 | \$688 | \$708 | \$729 | \$751 | \$774 | \$797 | \$821 | \$846 | \$871 | \$897 | | PV\$ | (e.g., maintenance) | Recurring | Discounted | ANNUAL RECURRING COSTS | DOE F Analysis |
| | 2030 | 2029 | 2028 | 2027 | 2026 | 2025 | 2024 | 2023 | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | | Date | Year | | | .01 | DOE Region: South |
| \$30,424 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$1,631 | \$1,674 | \$1,722 | \$1,766 | \$1,813 | \$1,866 | \$1,923 | \$1,990 | \$2,051 | \$2,106 | \$2,185 | \$2,277 | \$2,364 | \$2,463 | \$2,594 | \$0 | PV\$ | Costs | Total | Discounted | TOTAL COSTS | DOE Region: South Analysis Sector: Commercial |
| \$30,424 | \$30,424 | \$30,424 | \$30,424 | \$30,424 | \$30,424 | \$30,424 | \$30,424 | \$30,424 | \$30,424 | \$30,424 | \$30,424 | \$28,793 | \$27,119 | \$25,396 | \$23,631 | \$21,818 | \$19,952 | \$18,028 | \$16,039 | \$13,988 | \$11,882 | \$9,696 | \$7,420 | \$5,056 | \$2,594 | \$0 | PV\$ | Costs | Cumulative | Discounted | COSTS | |
| n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | | PV \$ | Savings | Cumulative | Discounted | CUMULATIVE SAVINGS | |
| n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | | yrs | Payback | Discounted | | Payback | |

The escalator analyzed above is assumed to be 10 years old, therefore it has approximately 15 years of remaining useful life. As a result the analysis just addresses the remaining 15 years.

Note:

The costs shown on this spreadsheet are the additional costs incurred by Standard Operation vs Slow Down mode.

They are comprised of \$1800/yr additional energy costs and \$924 /yr additional maintenance costs.

It is assumed that the Slow Down Escalator will save 2% of the \$46,200 annual maintenance cost or \$924/yr

| | 1 | S M | 24 | 23 | 22 | 21 | 20 | 19 | 8 | 17 | 16 | 5 | 14 | 3 | 12 | = | 6 | 9 | œ | 7 | 6 | 5 | 4 | ω | Ν | _ | 0 | # | Year | | | | |
|---------|---------------|---------|-----------------|-------------|-------------|----------|----------|----------|----------|----------|----------|-------------|-------------|-------------|----------|-------------|-------------|----------|-------------|-------------|-------------|-------------|-------------|-------------|-----------|-----------|-------------|-------------|---------------------|---|--------------------------|----------------------------|--|
| | | | | | | | | | | | | | | | | | | | | | | | | | | | First Cost | of Cost | Description | (e.g., 1st c | Inves | | Escalator I With VSD |
| \$8,300 | 0 | 9 | \$ 0 | \$ 0 | \$ 0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$ 0 | \$ 0 | \$ 0 | \$0 | \$ 0 | \$ 0 | \$0 | \$ 0 | \$0 | \$0 | \$8,300 | Constant \$ | | (e.g., 1st cost, replacement, residual) | nvestment-Related Costs | -NON | Escalator Retrofit with Slow Down Operation Analysis Month/Year-4/2006 Vrs before "On-Line":0 |
| \$8,300 | 6 | 9 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$8,300 | PV\$ | Discounted | nt, residual) | Costs | ANNUAL REC | 1 Slow Dov |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | n/a | of Cost | Description | (e.g., nor | Operat | NON-ANNUAL RECURRING COSTS | vn Operatio |
| \$0 | 6 | 60 | \$ 0 | \$ 0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$ 0 | \$0 | \$0 | \$0 | \$0 | \$0 | n/a | Constant \$ | | (e.g., non-annual maintenance, | Operations-Related Costs | STS | on Analysis Yrs befor |
| \$0 | 8 | 6 | \$ 0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | n/a | PV\$ | Discounted | enance) | Costs | | Analysis Month/Year:4 Yrs before "On-Line":0 |
| \$0 | 6 | 60 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | Constant \$ | Electric | Recurring | Annual | Е | 1/2006 |
| | 9.1 | 0.73% | 1.10% | 0.09% | 0.09% | 0.41% | 0.55% | 0.89% | 0.61% | 0.09% | 0.47% | 0.57% | 0.14% | 0.77% | 0.48% | 0.10% | -0.10% | -0.67% | -0.14% | 0.48% | -1.14% | -1.77% | -1.24% | -1.76% | -3.36% | -2.92% | | % | Escalation | Differential | Electric | ELECTRIC COSTS | Years of Years in |
| \$0 | ě | 9 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | | PV \$ | w/Fuel Esc. | Electric | Discounted | STS | Years of Project Service: 25 Years in Analysis Period 25 |
| \$0 | ě | 9 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | Constant \$ | | Recurring | Annual | N | e:25 d25 |
| | 0.00% | 0 00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | | % | Escalation | Differential | | NO 2ND FUEL USED | FE.M |
| \$0 | 6 | 9 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | | PV\$ | w/Fuel Esc. | | Discounted | JSED | FEMP Fiscal Year: 2006 Disc. Rate: 3.0% |
| \$0 | 6 | 8 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$ 0 | Constant \$ | (e.g., ma | Recurring | Annual | AN RECURRI | 2006 3.0% |
| \$0 | 6 | 60 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | | PV\$ | (e.g., maintenance) | Recurring | Discounted | ANNUAL RECURRING COSTS | DOE Analysis |
| | 0000 | 2020 | 2029 | 2028 | 2027 | 2026 | 2025 | 2024 | 2023 | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | | Date | Year | | | ТС | DOE Region: South |
| \$8,300 | ě | 9 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$8,300 | PV\$ | Costs | Total | Discounted | TOTAL COSTS | DOE Region: South Analysis Sector: Commercial |
| \$8,300 | #0,000 | 200 | \$8.300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | \$8,300 | PV \$ | Costs | Cumulative | Discounted | COSTS | |
| n/a | \$22, IZT | 233 134 | \$22.124 | \$22,124 | \$22,124 | \$22,124 | \$22,124 | \$22,124 | \$22,124 | \$22,124 | \$22,124 | \$22,124 | \$20,493 | \$18,819 | \$17,096 | \$15,331 | \$13,518 | \$11,652 | \$9,728 | \$7,739 | \$5,688 | \$3,582 | \$1,396 | (\$880) | (\$3,244) | (\$5,706) | (\$8,300) | PV \$ | Savings | Cumulative | Discounted | CUMULATIVE SAVINGS | |
| 3.4 | | | | | | | | | | | | | | | | | | | | | | | 3.4 | | | | | yrs | Payback | Discounted | | Payback | |

The additional hardware/equipment for slow down operation is the only cost. The hardware/equipment costs for a retrofit application is \$8300 vs. \$5550 for a new installation

Note:

Life-Cycle Costs Summary (Incremental 1st Costs Only, No Residual Costs) Elevator Motor VSD Savings Analysis

Life Cycle Comparison of 10 Year Old Escalator with Standard Operation vs. Retrofitted Slow Down Operation

| | peration With VSD ** LCC Ch ** Simple | | * alte ** alte | peration With VSD | Base No Va | | Case | | |
|---|--|--|--|-------------------|------------------------------|------------------|--------------|------------|----------------------------------|
| Analysis Assumptions: | With VSD * LCC Choice ** Simple Payback choice | | * alternative with least life-cycle cost ** alternative with most rapid simple payback | VSD | Base No Variable Speed Drive | | Description | | |
| | (\$8,300) | | ayback | \$8,300 | \$0 | | €9 | 1st year | One-Tin |
| # of Ye | (\$8,300) | | | \$8,300 | \$0 | | | LCC | One-Time Costs |
| Real D ars before P | \$1,800 | | | \$0 | \$1,800 | | €9 | 1st year | |
| DOE/FEMP Fiscal Year Real Discount Rate for this Analysis Number of Analysis Years # of Years before Project Occupancy or Opration DOE Fuel Price Escalation Region Analysis Sector | (\$8,300) (\$8,300) \$1,800 \$24,306 \$19,393 \$924 \$11,031 \$29,866 including 1st yi | Life-Cycle S | | \$0 | \$24,306 | | PV\$ | Undisc LCC | Total Utility |
| DOE/FEMP Fiscal Year nt Rate for this Analysis umber of Analysis Years Occupancy or Opration Price Escalation Region Analysis Sector | \$19,393 | AVINGS (| | \$0 | \$19,393 | | PV\$ | LCC | |
| 2006 3.0% 5 25 0 0 3 | \$924 | negative | | \$0 | \$924 | Life-Cyc | s | 1st year | Mair |
| (South) (Commercial) | \$11,031 | entries in | | \$0 | \$924 \$11,031 | Life-Cycle COSTS | PV \$ | LCC | Maintenance |
| | \$29,866 \$22,124 \$22,124 including 1st yr maintenance cost savings: | Life-Cycle SAVINGS (negative entries indicate increased costs) | | \$8,300 | \$38,166 | | PV\$ | Undisc LCC | Total |
| | \$22,124 \$22,124 naintenance cost savings | ed costs) | | \$8,300 | \$30,424 | | PV\$ | LCC | Total |
| | \$22,124 ost savings: | | | n/a | n/a | I | | Savings | |
| | 4.6 3.05 | • | | n/a | n/a | | yrs | Payback | Simple |
| | 3.39 | | | n/a | n/a | | yrs | Payback | Discnt'd |
| | \$8,300 | | | \$8,300 | | | yrs yrs PV\$ | Related | Investment |
| | \$30,424 | | | \$0 | \$30,424 | | | Related | Operations |
| | 3.67 | | | n/a | n/a | | SIR | Ratio | Saving -to- Invest |
| | 8.49% | | | n/a | n/a | | AIRR | Return | Adjusted Internal Rate-of- |

Simple payback is defined as the Investment Cost divided by the first year savings. The BLCC5 program does not recognize maintenance savings in this calculation. The simple payback period in years using the BLCC5 program is 4.6 years. If the maintenance savings are included in the calculation the payback period is reduced to 3.05 years.

BUILDING LIFE-CYCLE COST ANALYSIS

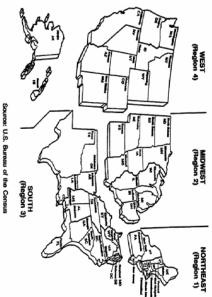
Life Cycle Cost Comparison to Determine Required Energy Savings (or slow Down Mode time) for 7 year Discounted Payback updated: 1 April 2006

Life Cycle Cost Calculation for 7 Year Discounted Payback

User input fields are indicated in blue. uld be updated (replaced) every April, after DOE relev

IMPORTANT NOTE: This spr

| | | | Uni | | | (0=None, 1=N.Gas; 2=LP0 | | | (1=Reside | | | (1 through 4 | | | | | | Į. | | | | | | | | | Visit http://www.doe2.com to download the current copy. |
|---|-------------------------|--|---|----|----|---|-----------------------|-------|---|-----------------|--------------------|--|---|----------|---------------------------------|--------------------------|---|--------------------------------------|---------|------------------------------|-------------------------|------------|----------------------|----------|---------------------------------|--------|---|
| 7 | WEST (Region 4) | | Uniform Electric Price Escalation Rate | | | (0=None, 1=N.Gas; 2=LPG, 3=Dist Oil; 4=Resid Oil; 5=Coal) | Second Fuel Type | | (1=Residential; 2=Commercial; 3=Industrial) | Analysis Sector | | (1 through 4, see map below, 5=U.S. average) | DOE Fuel Price Escalation Region | | Number of Project Service Years | Number of Analysis Years | | Real Discount Rate for this Analysis | | Year Project comes "On-Line" | Year Analysis Performed | | DOE/FEMP Fiscal Year | | Basic Data, this analysis | | Visit http://www.doe2.com to download the current copy. |
| | (Reg | | | | | | 0 | | | 2 | | | ω | | 25 | 25 | | 3.0% | | 2006 | 2006 | | 2006 | | sis | | com to do |
| | MIDWEST (Region 2) | (10 use DOE et | (to use DOE ex | | | | (None) | | | (Commercial) | | | (South) | | | | | | | | | | | | | | ownload the current co |
| > | NORTHEAST (Region 1) | (to use DOE escalation rates, within valy by year, reave this entity entply) | (to use DOE escalation rates, which vary by year, leave this entry empty) | | | | | | Real-to-Nominal: | | | | Nominal-to-Real: | Convert: | | | * "nominal" assume | 30-year | 10-year | 7-year | 5-year | OMB 3-year | DOE/FEMP | | FY 2006 Federal Discount Rates: | | ру. |
| | | ру уваг, | by year, | | | | 4.6% | 1.60% | 3.0% | | 3.0% | 1.60% | | | | | s 1.75% | r 3.0% | r 2.8% | r 2.7% | | | 3.0% | real | iscount | | |
| | | leave uns enu y empty) | leave this entry empty) | | | | Nominal Discount Rate | | Real Discount Rate | | Real Discount Rate | General Inflation Rate | Nominal Discount Rate | | | | * "nominal" assumes 1.75% effective general inflation | 4.6% | 4.4% | | 4.2% | | 4.6% | nominal* | Rates: | | |
| | | 25 25 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 1 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | ω | 2 | _ | Year ≠ | |
| | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | Occ/Use |



| | 25 | 24 | 23 | 23 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | = | 10 | 9 | œ | 7 | 6 | Ŋ | 4 | ω | 2 | _ | 0 | # | Year | | | | |
|---------|----------|-------------|-------------|-------------|---------|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------|---------|---------|-----------|-----------|-----------|-----------|-----------|-------------|-------------|---------------------|---|---|----------------------------|--|
| | Residual | | | | | | | | | | Replace | | | | | | | | | | | | | | | First Cost | of Cost | D | (e.g., 1st c | - | | Escalator - Calculation |
| \$5,550 | \$0 | \$ 0 | \$ 0 | \$ 0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$5,550 | Constant \$ | | (e.g., 1st cost, replacement, residual) | mont Polator | NON- | Escalator - Standard Operation Calculations for 7 year payback |
| \$5,550 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$5,550 | PV \$ | Discounted | nt, residual) | Cont | NON-ANNUAL RECURRING COSTS | Operation r payback |
| | | | | | | Overhaul | | | | | | | | | | | | Overhaul | | | | | | | | n/a | of Cost | Description | (e.g., non | Opporati | CURRING CO | |
| \$0 | \$0 | \$ 0 | \$ 0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | n/a | Constant \$ | | (e.g., non-annual maintenance) | on Polatod | STS | Analysis N Yrs before |
| \$ | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | n/a | PV \$ | Discounted | enance) | 2 | | Analysis Month/Year: 4/2006 Yrs before "On-Line": 0 |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$ 0 | Constant \$ | Electric | Recurring | 2 | Е | /2006 |
| | 0.72% | 1.10% | 0.09% | 0.09% | 0.41% | 0.55% | 0.89% | 0.61% | 0.09% | 0.47% | 0.57% | 0.14% | 0.77% | 0.48% | 0.10% | -0.10% | -0.67% | -0.14% | 0.48% | -1.14% | -1.77% | -1.24% | -1.76% | -3.36% | -2.92% | | % | Escalation | Differential | П 0 1 1 1 1 1 1 1 | ELECTRIC COSTS | Years of F Years in A |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | | PV\$ | w/Fuel Esc. | Electric | | iTS | Years of Project Service: 25 Years in Analysis Period: 25 |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$ 0 | Constant \$ | | Recurring | 2 | N C | i: 25 |
| | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | | % | Escalation | Differential | | NO 2ND FUEL USED | FEME |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | | PV \$ | w/Fuel Esc. | Discounted | | JSED | FEMP Fiscal Year: Disc. Rate: |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$ 0 | Constant \$ | (e.g., ma | Recurring | A . | RECURRI | 2006 3.0% |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | | PV\$ | (e.g., maintenance) | Recurring | Discounted | ANNUAL COSTS | DOE F Analysis |
| | 2030 | 2029 | 2028 | 2027 | 2026 | 2025 | 2024 | 2023 | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | | Date | Year | | | 70 | DOE Region: South |
| \$5,550 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$5,550 | PV \$ | Costs | Total | | TOTAL COSTS | DOE Region: South Analysis Sector: Commercial |
| \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5,550 | \$5.550 | \$5,550 | PV \$ | Costs | Cumulative | Discount of | COSTS | |
| n/a | \$10,264 | \$9,813 | \$9,351 | \$8,881 | \$8,398 | \$7,900 | \$7,390 | \$6,867 | \$6,333 | \$5,786 | \$5,224 | \$4,647 | \$4,057 | \$3,449 | \$2,829 | \$2,192 | \$1,537 | \$862 | \$162 | (\$560) | (\$1,300) | (\$2,071) | (\$2,880) | (\$3,723) | (\$4.608) | (\$5,550) | PV \$ | Savings | Cumulative | Discounted | CUMULATIVE | |
| 6.8 | | | | | | | | | | | | | | | | | | | 6.8 | | | | | | | | yrs | Payback | Discounted | 3 | Pavhack | |

| | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 3 | 12 | 1 | 10 | 9 | œ | 7 | 6 | Ŋ | 4 | ω | 2 | _ | 0 | * | Year | | | | |
|----------|-------------|----------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------|---------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------|-------------|-------------|---------------------------|---|--------------------------|----------------------------|---|
| | | | | | | | | | | | | | | | | | | | | | | | | | | First Cost | of Cost | Description | (e.g., 1st c | Inves | | Escalator - Standard Operation Calculations for 7 year payback |
| \$0 | \$ 0 | \$0 | \$ 0 | \$0 | \$0 | \$ 0 | \$0 | \$0 | Constant \$ | | (e.g., 1st cost, replacement, residual) | Investment-Related Costs | NON- | Standard |
| \$0 | \$0 | \$0 | \$0 | | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | PV \$ | Discounted | ent, residual) | d Costs | NON-ANNUAL RECURRING COSTS | Operation or payback |
| | | | | | | | | | | | | | | | | | | | | | | | | | | n/a | of Cost | Description | (e.g., no | Opera | CURRING CO | |
| \$0 | \$ 0 | \$0 | \$ 0 | \$0 | \$0 | \$ 0 | \$0 | n/a | Constant \$ | | (e.g., non-annual maintenance) | Operations-Related Costs | STS | Analysi Yrs befo |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | n/a | PV\$ | Discounted | ntenance) | d Costs | | Analysis Month/Year:4/2006 Yrs before "On-Line":0 |
| \$25,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | \$1,000 | Constant \$ | Electric | Recurring | Annual | | :4/2006 :0 |
| | 0.72% | 1.10% | 0.09% | 0.09% | 0.41% | 0.55% | 0.89% | 0.61% | 0.09% | 0.47% | 0.57% | 0.14% | 0.77% | 0.48% | 0.10% | -0.10% | -0.67% | -0.14% | 0.48% | -1.14% | -1.77% | -1.24% | -1.76% | -3.36% | -2.92% | | % | Escalation | Differential | Electric | т | |
| \$22,719 | \$944 | \$938 | \$928 | \$927 | \$926 | \$922 | \$917 | \$909 | \$903 | \$903 | \$898 | \$893 | \$892 | \$885 | \$881 | \$880 | \$881 | \$887 | \$888 | \$884 | \$894 | \$910 | \$922 | \$938 | \$971 | 1.0000 | PV \$ | (no discount) | only | Escalated | ELECTRIC COSTS | |
| \$17,413 | \$478 | \$492 | \$507 | \$522 | \$538 | \$554 | \$570 | \$587 | \$605 | \$623 | \$642 | \$661 | \$681 | \$701 | \$722 | \$744 | \$766 | \$789 | \$813 | \$837 | \$863 | \$888 | \$915 | \$943 | \$971 | | PV\$ | i) (no fuel esc) | only | Discounted | STS | Years of F Years in <i>I</i> |
| \$15,814 | \$451 | \$461 | \$470 | \$484 | \$498 | \$510 | \$523 | \$534 | \$547 | \$562 | \$577 | \$590 | \$607 | \$621 | \$636 | \$655 | \$675 | \$700 | \$722 | \$740 | \$771 | \$809 | \$843 | \$884 | \$942 | | PV\$ | × | Electric | Discounted | | Years of Project Service:25 Years in Analysis Period25 |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | Constant \$ | _ | Recurring | Annual | z | e: 25 d 25 |
| | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | | % | Escalation | Differentia | | NO 2ND FUEL USI | FEMP |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | | PV\$ | w/Fuel Esc. | | Discounted | JSED | 1P Fiscal Year: 2006 Disc. Rate: 3.0% |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$ 0 | Cor | | Recurring | Annual | RECURF | r: 2006 r: 3.0% |
| \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | \$0 | | PV\$ | (e.g., maintenance) | Recurring | Discounted | ANNUAL RECURRING COSTS | DOE Analysi |
| | 2030 | 2029 | 2028 | 2027 | 2026 | 2025 | 2024 | 2023 | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | | Date | Year | | | 7 | DOE Region: South alysis Sector: Comm |
| \$15,814 | \$451 | \$461 | \$470 | \$484 | \$498 | \$510 | \$523 | \$534 | \$547 | \$562 | \$577 | \$590 | \$607 | \$621 | \$636 | \$655 | \$675 | \$700 | \$722 | \$740 | \$771 | \$809 | \$843 | \$884 | \$942 | \$0 | PV\$ | Costs | Total | Discounted | TOTAL COSTS | DOE Region: South Analysis Sector: Commercial |
| \$15,814 | \$15,814 | \$15,363 | \$14,901 | \$14,431 | \$13,948 | \$13,450 | \$12,940 | \$12,417 | \$11,883 | \$11,336 | \$10,774 | \$10,197 | \$9,607 | \$8,999 | \$8,379 | \$7,742 | \$7,087 | \$6,412 | \$5,712 | \$4,990 | \$4,250 | \$3,479 | \$2,670 | \$1,827 | \$942 | \$0 | PV\$ | Costs | Cumulative | Discounted | COSTS | |
| n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | | PV \$ | Savings | Cumulative | Discounted | CUMULATIVE SAVINGS | |
| n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | | yrs | Payback | Discounted | | Payback | |

NOTE: User input fields are indicated in blue.
You may wish to hide columns J, K, O, & P

Life-Cycle Costs Summary (Incremental 1st Costs Only, No Residual Costs) Intermittent/Slow Down Escalator, 7 Year Discounted Payback Analysis

| | peration #REF! * <i>LCC</i> **S <i>im</i> | * alter ** alter | Base Calculate peration #REF! | | Case | |
|---|---|---|---|------------------|--|----------------------------------|
| Analysis Assumptions: | #REF! * LCC Choice ** Simple Payback choice | * alternative with least life-cycle cost ** alternative with most rapid simple payback | Base Calculations for 7 year payback ration #REF! | | Description | |
| | (\$5,550) | yback | \$0 \$5,550 | | 1st year \$ | One-Tin |
| # of Ye | (\$5,550) (\$5,550) \$1,000 | | \$0 \$5,550 | | PV \$ | _ |
| Real [ars before F | | | \$1,000 \$0 | | 1st year \$ | |
| DOE/FEMP Fiscal Year Real Discount Rate for this Analysis Number of Analysis Years # of Years before Project Occupancy or Opration DOE Fuel Price Escalation Region Analysis Sector | \$22,719 \$15,814 | Life-Cycle S | \$22,719 \$0 | | Undisc LCC PV\$ | Total Utility |
| DOE/FEMP Fiscal Year nt Rate for this Analysis umber of Analysis Years Occupancy or Opration Price Escalation Region Analysis Sector | \$15,814 | AVINGS (| \$15,814 \$0 | | PV\$ | |
| 2006 3.0% 5 25 0 0 3 | \$0 | negative | \$ 80 | Life-Cyc | 1st year \$ | Mair |
| (South) (Commercial) | \$0 | entries in | \$0 80 | Life-Cycle COSTS | PV \$ | Maintenance |
| | \$17,169 \$10,264 \$10,264 including 1st yr maintenance cost savings: | Life-Cycle SAVINGS (negative entries indicate increased costs) | \$22,719 \$5,550 | | Undisc LCC PV\$ | Total |
| | \$10,264 \$10,264 naintenance cost savings | ed costs) | \$15,814 \$5,550 | | PV\$ | Total |
| | \$10,264 ost savings: | | n/a n/a | l | Savings NS | N et |
| | 5.6 5.55 | | n/a n/a | | Payback <i>yrs</i> | Simple |
| | 6.78 | | n/a n/a | | Payback yrs | Discnt'd |
| | \$5,550 | | \$0 \$5,550 | | Payback Payback Related yrs yrs PV \$ | Investment |
| | \$15,814 | | \$15,814 \$0 | | Related PV\$ | Operations |
| | 2.85 | | n/a n/a | | SIR | Saving -to- Invest |
| | 7.41% | | n/a n/a | | AIRR | Adjusted Internal Rate-of- |

#

Appendix E

From: Analysis of Maintenance and Safety Considerations with Reduced Speed Operation during Off-Peak Periods, submitted be NEII to the ASME Subcommittee on Escalators and Moving Walks, TN 02-2375, dated 11/13/02

Safety Considerations

In normal operation riders will never be on the escalator or moving walk during the acceleration, deceleration or reduced speed operating modes. The sensor station will detect approaching passengers, and if the unit is running at reduced speed, it will accelerate to full speed before the passenger boards the moving steps. Also, deceleration to reduced speed will occur only after a timed period long enough to insure that all riders have exited the escalator or moving walk before deceleration is initiated. To account for the remote possibility that a rider is on the unit during the change of speed mode the acceleration/deceleration rates should be limited to 1.0 ft/sec². Accelerations and decelerations of 1.0 ft/sec² have been shown to be completely safe for riders of passenger conveyances. Two studies previously presented to the A17.1 Committees (see Note #1) have shown that no destabilization of standing persons occurs during acceleration or decelerations of 1.0 ft/sec² or less. These, (sic) two studies are summarized below.

- "Human Engineering Studies of High Speed Passenger Conveyers" A.C. Browning
 - This study assessed the upsetting effect or staggering movement of standing passengers riding on a simulated conveyer due to various acceleration rates. A propelled wheeled platform was used. The platform speed and acceleration rate could be precisely controlled. Approximately 1000 different persons, including young children and adults up to 85 years of age, were tested. The acceleration periods were limited to between 0.5 and 2.0 seconds. Observers recorded the effect of acceleration on the riding standees into the categories of no relative movement, slight relative movement and moderate relative movement. The observation results were broken down into two groups fit adults and the general public (all age groups including the general public). ... [N]o relative movement of the standing passengers is experienced by the general public with accelerations of 1.3 ft/sec² or less and for fit adults with accelerations of 2.1 ft/sec² or less.
- "Disturbing Effects of Horizontal Acceleration" C.F. Hirshfield The data given in this report summarizes the effects on unsupported standees due to horizontal accelerations of 1.0 to 8.0 ft/sec². Maintenance of equilibrium of the unsupported standing persons is based on the percentages of riders that do not experience any foot movement (they have no significant loss of balance). ...

[T]he data shows (sic) that 99% of the unsupported standing riders maintain equilibrium (have no foot movement) during accelerations of 1.0 ft/sec² or less and 95% of the riders maintain equilibrium during accelerations of 2.0 ft/sec² or less.

Experience with the escalators installed in Calgary and Vancouver using the reduced speed operation with acceleration and deceleration rates of 1.0 ft/sec² is that they provide comfortable and safe operation for all persons including those riding the units during testing of the acceleration/deceleration modes.

It can therefore be concluded that acceleration or decelerations not greater than 1.0 ft/sec² are completely safe for all escalator or moving walk passengers.

Note #1 – The above studies have been previously presented at A17.1 Committee meetings in connection with other topics as follows:

- C.E. Browning Data Presented at the A17.1 Main Committee Meeting Dec. 14 & 15, 1994 by Mr. G. Gibson. The report is included in the meeting minutes Item 14.9 regarding TR92-75.
- C.F. Hirshfield Data Presented at the A17.1 Escalator and Moving Walk Committee Meeting Sept. 16 & 17, 1999 by Mr. T. Nurnberg and Mr. B. McClintock. The report is included in the meeting minutes Item 20.2 regarding TR98-30 and TR95-42.

- End of Quoted Material -

We note that the value of the studies cited above to prove the safety of intermittent escalators was questioned by a respondent. Respondent stated that it appeared the data based on horizontal movement was applied blindly to evaluate the safety of the incline movement of escalators. The ASME Escalator and Moving Walk Committee responded to that concern as follows: "The data is not applied blindly to incline movement. The horizontal component of the incline acceleration is 86% of the horizontal acceleration rate from the study."

Appendix F

New York City Transit (NYCT) Comments on the use of Intermittent Escalators

Unlike most owners, New York City Transit (NYCT) operates its escalators 24 hours a day. In addition, NYCT's cost of new escalators is higher than this study considers. As a result, the energy savings and increased useful life benefits are anticipated to be even greater for NYCT than this study suggests. With these benefits in mind, NYCT has been interested in the use of intermittent escalators, specifically sleep mode operation, for some time.

In February 2004, NYCT submitted to New York State a request for a variance from ASME A17.1 to be able to use sleep mode on escalators being installed at the Herald Square Station, in Manhattan. The specific operational features of sleep mode proposed by NYCT were based on a proposal for sleep mode that was, at that time, being considered by the ASME A17.1 Escalator and Moving Walk Committee. NYCT's request for a variance was granted and subsequent variances were granted for other stations in the NYCT system. In addition to the operational features of sleep mode required by the variance, NYCT has also incorporated several additional operational features into sleep mode operation.

While NYCT has escalators being installed with the capability of sleep mode operation, NYCT has not determined if sleep mode operation will be enabled when the escalators are placed into service.

Attached are the following documents:

- Approved variance from New York State to allow sleep mode operation on escalators at Herald Square Station.
- Description of the additional measures that NYCT incorporated into the design of sleep mode, not specifically required by the approved variance.



STATE OF NEW YORK DEPARTMENT OF STATE 41 STATE STREET ALBANY, NY 12231-0001

In the Matter of the Petition of:
Metropolitan Transportation Authority
New York City Transit
For a Variance to the New York State
Uniform Fire Prevention and Building Code

DECISION

RANDY A. DANIELS SECRETARY OF STATE

PETITION NO. 2004-0192

Upon the application of Metropolitan Transportation Authority/New York City Transit, filed pursuant to 19 NYCRR 1205 on March 4, 200,4 and upon all other papers in this matter, the Department makes the following determination:

NATURE OF GRIEVANCE AND RELIEF SOUGHT

The petition pertains to alterations to a Group A-3 (assembly - passenger subway station) occupancy, known as the "Herald Square Station" and located at Herald Square and 34th Street, City of New York, County of Manhattan, State of New York.

Relief is requested from:

19 NYCRR Part 1221, The Building Code of New York State, Section 3001.2, which requires that except as otherwise provided for in the code, the design, construction, installation, alteration, repair and maintenance of elevators and conveying systems and their components shall conform to ASME A17.1-00 Safety Code for Elevators and Escalators. [The petitioner requests escalators not complying with ASME A17.1-00.]

FINDINGS OF FACT

- Twelve escalators are proposed to be replaced at the Herald Square/34th Street Subway Station. The
 petitioner requests that variable speed escalators be permitted.
- 2. Section 3001.2 requires that except as otherwise provided for in the code, the design, construction, installation, alteration, repair and maintenance of elevators and conveying systems and their components shall conform to ASME A17.1-00 Safety Code for Elevators and Escalators. ASME A17.1-00 Section 6.1.4 requires that the speed attained by an escalator after startup shall not be intentionally varied.
- 3. In general, variable speed escalators running at full speed with no passengers will gradually reduce speed into a "sleep mode." When a passenger is detected by sensors located at the escalator entrance, the

escalator gradually returns to full speed. Advances in technology have been made to allow very gradual and precise acceleration and deceleration of moving escalators, such that safety is not compromised.

- 4. Because the New York City Transit escalators run 24 hours per day and may be unused for long periods, running escalators using "sleep mode" operation offers distinct advantages by reducing energy consumption and wear of the escalator components, thereby increasing life expectancy.
- 5. The petitioner indicates that the following guidelines would be followed: acceleration and deceleration rates shall not exceed 1.0 ft/sec²; the minimum speed of the escalators shall not be less than 10 ft./min.; the speed of the escalators shall not be varied during inspection operation mode. These same requirements are currently proposed as a revision to the next edition of ASME 17.1.
- Studies have shown that acceleration/deceleration rates of 1.0 ft/sec² are completely comfortable and safe.
- The code compliance manager for MTA/NYCT supports the granting of a routine variance under the provisions of 19 NYCRR 1205.6.

CONCLUSIONS OF LAW

Strict compliance with the provisions of the Uniform Fire Prevention and Building Code would entail a change so slight so as to produce a negligible additional benefit consonant with the purpose of the Code, and would be unnecessary in light of the alternative which is compliance with the proposed revised standard. This alternative will ensure the achievement of the Code's intended objective, such that granting the requested relief would not substantially adversely affect the Code's provisions for health, safety and security.

DETERMINATION

WHEREFORE IT IS DETERMINED that the application for a variance from 19 NYCRR Part 1221, Section 3001.2, to permit variable speed escalators, be and is hereby PROPOSED TO BE GRANTED with the following condition:

 That all conditions, enhancements and equipment offered by the petitioner be installed as described, and in accordance with the applicable reference standards.

This DECISION is issued under 19 NYCRR 1205.6. Unless objected to by the petitioner in a writing received by the department, the decision shall become FINAL after fifteen days of receipt of the decision by the parties.

This decision is limited to the specific building and application before it, as contained within the petition, and should not be interpreted to give implied approval of any general plans or specifications presented in support of this application.

Ronald E. Piester Director, Codes Division

DATE: 6/15/104 EK:sg

The additional measures that NYCT incorporated into the design of sleep mode, not specifically required by our variance to NYS (nor proposed by ASME):

- 1. We provided entrance/exit stanchions located several feet away from the escalator comb/step interface. There are railings between the stanchion and the escalator that prevent passengers from bypassing the stanchions. The purpose of the stanchion is twofold.
 - a. To provide a visual indicator to inform passengers whether to enter the escalator or not. A green arrow is displayed if the escalator is moving away form the entrance; indicating passengers may enter. A red X (international symbol for DO NOT ENTER) is displayed if the escalator is traveling toward the passenger; indicating that they should not enter the escalator.
 - b. The sensors are located in the stanchion so the escalator will likely be up to full speed before passengers board it. The reason ASME limited the acceleration/deceleration rate to no greater than 1 ft/sec/sec is that studies show this acceleration rate is safe. Our personal experience (from factory tests) riding the escalator at these acceleration rates, in our opinion, confirms that this acceleration rate is safe. Nevertheless, we intend to accelerate the escalator before passengers board it.
- 2. We provided two sensors at each landing, located at 12" and 36" AFF. The two heights ensure that all passengers, even small children, can not evade the sensors. Redundant sensors are provided to ensure that there is always a working sensor. The assumption is that the sensors won't fail simultaneously. (These sensors typically have MTBF rating of 1,000,000 cycles.) The sensors are compared against each other to detect if a sensor fails. If any senor fails, the escalator will not operate in sleep mode.
- 3. We decreased the deceleration rate even further; from 1.0 to 0.5 ft/sec/sec. The deceleration rate and acceleration rate are different in that the acceleration rate has competing objectives. We want to get the escalator up to full speed fast so it is at full speed when passengers board the escalator and we also want the acceleration rate low enough to be safe if a passenger does get on an accelerating escalator. The deceleration of the escalator can be as low as we want with no performance or safety drawbacks at all.
- 4. We addressed a scenario not contemplated by ASME (or any other existing user of sleep mode that we are aware of). The scenario is when a passenger, either intentionally or unintentionally, attempts to enter an escalator traveling toward them while the escalator is operating in sleep mode. The response to this scenario is that a bell rings three times (it is the same bell that rings when the escalator is starting) when the passenger passes the sensors and the escalator exits sleep mode (i.e. it accelerates to full speed). The theory behind this is as follows:
 - a. The bell is to alert passengers that they are going the wrong way.
 - b. Accelerating the escalator up to full speed ensures that persons with impaired vision will not mistake a slow moving escalator for a stopped escalator and attempt to get on it. It also discourages passengers from attempting to walk down a slow moving escalator in an attempt to bypass a crowded stair or other escalator. Most importantly, if a passenger was allowed to walk on a slow moving escalator, in the opposite direction, it could accelerate if a passenger entered the escalator at the entrance landing.
- 5. The wiring from the sensors to the controller is designed in a failsafe manner. If the wiring is cut or disconnected the escalator will not operate in sleep mode.

